

# Corrosion

Official Publication of  
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



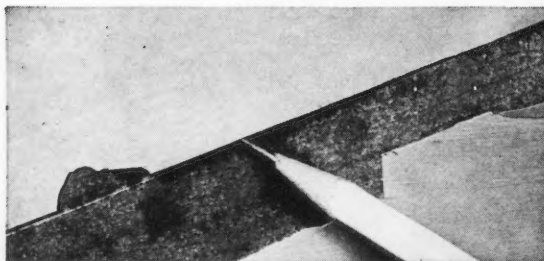
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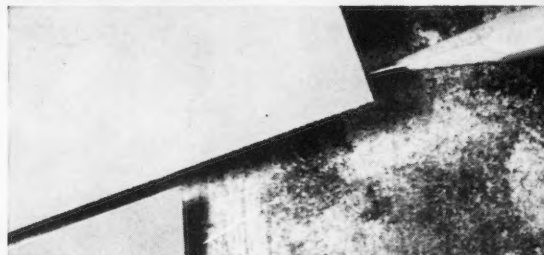
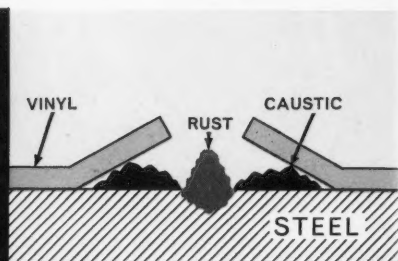
IRON

# PUZZLED ABOUT PRIMERS?

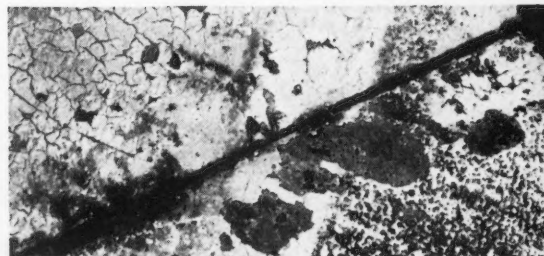
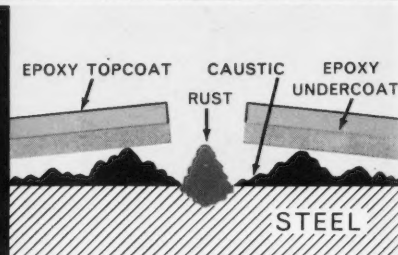
## Here are tests you can duplicate



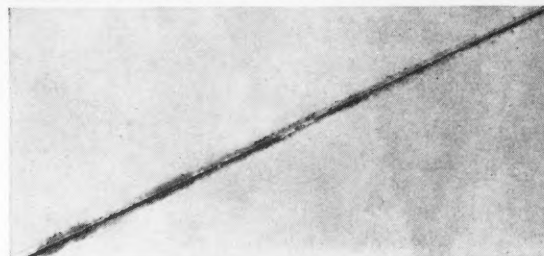
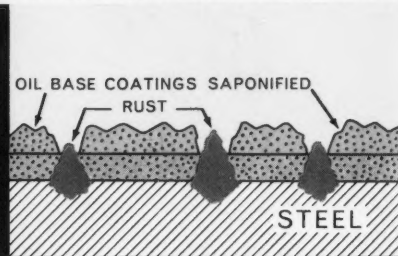
**TEST 1**—One coat of self-priming vinyl. Coating breaks away (L) due to severe undercutting (R), exposing metal to progressive corrosion.



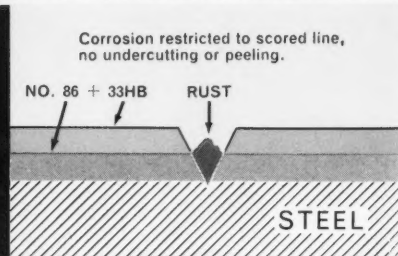
**TEST 2**—Epoxy primer, epoxy topcoat. Coating lifts off in single sheet (L) as adhesion fails (R), exposing entire surface to corrosion.



**TEST 3**—Oil primer, oil topcoat. Both coats fail completely (L) as underfilm caustic reacts on their oils to form soaps (R).



**TEST 4**—Amercoat's No. 86 inhibitive primer and No. 33HB vinyl topcoat. Corrosion restricted to scored line (L), no undercutting or peeling (R).



The purpose of these accelerated tests is to show what happens when various types of coatings are exposed to a typical corrosive environment. Four clean steel panels, free from mill scale and rust, were coated with different combinations of primers and topcoats. Each was scribed to bare metal and immersed in salt water in the presence of free oxygen, for two weeks.

As caustic deposits formed over cathodic areas of the steel in tests 1, 2 and 3, failure occurred in three ways. The vinyl, though not directly attacked, was undercut as caustic

spread beneath the film and destroyed adhesion. The epoxy coating, known for critical adhesion to smooth metal, proved impervious to caustic attack. It was, however, lifted in its entirety as moisture spread beneath the surface. The entire oil paint film was quickly penetrated by the salt solution, creating widespread corrosion and caustic formation. The caustic then reacted with the oil to saponify the film.

In the fourth test the corrosion was limited to the score mark. Reason: Amercoat No. 86 Primer resists undercutting and adheres tenaciously,

inhibiting electrolytic corrosive action.

The conclusions are clear. To provide long term protection in corrosive service, start with Amercoat No. 86 Primer, which provides a sound and lasting base for quality topcoats such as Amercoat No. 33HB.

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After the first month of operation, overhead vapor line and reflux line of silica tower and clay tower had to be replaced. Reflux pump and reactor charge pump had to be relined and new impellers installed. Severe corrosion was noted in condenser bundles. Throttling valves were renewed several times.

KONTOL was then injected into the overhead vapor line from the prefractionator. Corrosion test coupons installed in a by-pass on the reflux line revealed the following results:

Date Installed	Date Removed	M. P. Y.*	Kontol
12/18	12/26	11.74	No
12/26	1/2	7.96	Yes
1/19	2/2	.41	Yes
2/2	2/23	.17	Yes
2/23	4/28	.12	Yes
5/13	10/12	.14	Yes

\*Mils penetration per year

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devoted entirely to corrosion  
research and control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., as a permanent record of progress in corrosion control.

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Corrosion Protection for Pipe Type Transmission Lines by Wellon T. Rose	Reinforced Plastics for Corrosion Control by W. A. Severance
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Effect of the Concentration of Various Salts on the Dissolution of Cadmium in Air Saturated Solutions by C. J. Boone and Cecil C. Lynch	A New Inorganic Cement Mortar for Sulfuric Acid Service by Robert S. Mercer
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### Next Month in Technical Topics

Some Corrosion Problems of Tank Trucks and Their Solutions by Louis Reznak, National Tank Truck Carriers, Inc., Washington, D.C.

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**THIS MONTH'S COVER**—This 12-inch steel casing from a salt water source well was removed after 1½ years' service because all but a few openings were clogged with corrosion products. The few still open have been greatly enlarged by corrosion. Corrosion products completely clogged the gravel bed surrounding the casing, cementing it into almost a solid piece.



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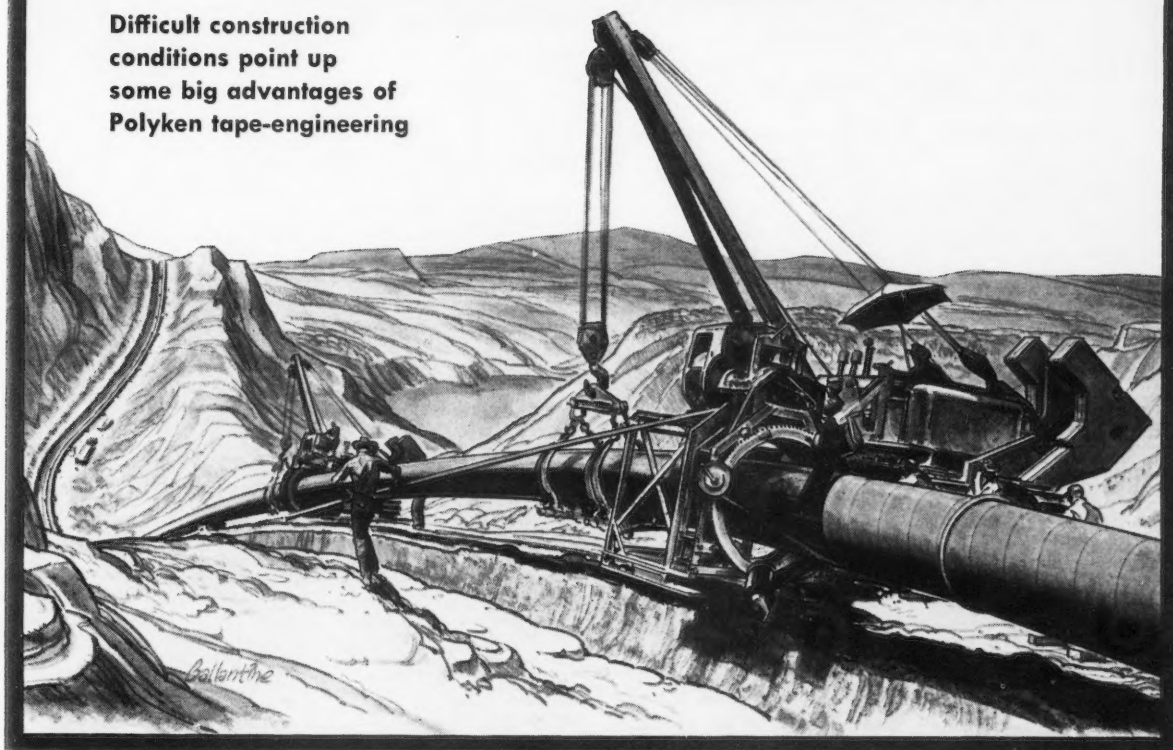
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(Continued on Page 8)



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## News about COATINGS for METALS

Metallic.....Organic.....Decorative.....Protective

# Plastisol coating seals out corrosion

## Tank lining has built-in visual cure control

One of a group of Unichrome drum and tank lining materials, Coating B-124 is an unusual phenolic type material. When wet, it is gray in color. When fully cured, it is olive drab. This color change gives visual security against "half-baked" protection especially in large tanks and tank cars where heat application may be uneven.

Also in this coating group will be found several pigmented coatings which yield 2-mil thicknesses per coat. That's double the build-up of ordinary phenolic coatings. Obviously, fewer coats are needed, cutting time and costs.

### APPLICATOR SERVICE

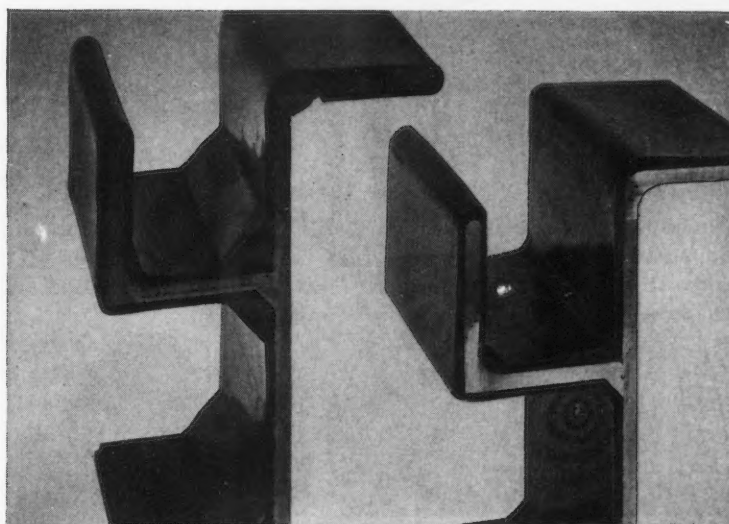
Specialist firms experienced in applying Unichrome lining materials are located across the country. They are well set up to handle even large equipment shipped to them. They can provide fast service, and the uniform coating with greater impact resistance and improved protection for which Unichrome Phenolic Linings are noted. Send for names.



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*Unichrome "Super 5300" Coating sprays  
seamless, pore-free lining  
with outstanding resistance to abrasion*



Section at left shows how sheet linings are applied, with seams at all sharp bends. Contrast this with the continuous, seamless "Super 5300" lining on section at right. There are no weak spots where solutions could undercut lining.

Chemical and corrosion engineers involved in new construction have shown keen interest in the advantages of Unichrome "Super 5300" Coating. Especially since it is a sprayable material, and can be applied up to 60 mils thick per coat to any object that can be heated to required baking temperature.

### MEETS THREE IMPORTANT REQUIREMENTS

(1) Unlike usual sheet materials of rubber and plastic, "Super 5300" Coating poses no problem with seams. Since it is a liquid material, it forms a continuous coating without air pockets, eliminating potential sources of trouble, even on complicated shapes. (2) Thick and pore-free, it presents no paths for corrosive chemicals to travel to base metal. (3) It withstands abrasion

and impact to a remarkable degree. Thus, it securely "seals" against corrosive attack due to penetration or to damage encountered with ordinary protective coatings.

### INHERENT CORROSION RESISTANCE

A vinyl material, "Super 5300" Coating naturally resists a broad range of acids, alkalis, moisture and other active agents. Should the need arise, equipment with this coating can be patched and spot rebaked, to reform an impervious "armor" good as new.

"Super 5300" can be applied in-plant; or by expert applicators in key locations who can promptly and proficiently coat the equipment you ship them. Write Metal & Thermit for names. Or for Bulletin Chem-C-3.

# TITANIUM—available now for long service

## NOW AVAILABLE: TITANIUM CASTINGS



● This 2" titanium globe valve, cast by Oregon Metallurgical Corp., is corrosion-resistant, has low density with a tensile strength up to 90,000 psi. Such castings are now possible by use of an expendable graphite mold composition developed through Du Pont research.

New casting technique produces sound, high-quality shapes at fraction of machined part cost

For the first time, *cast* titanium shapes are readily available—such as the globe valve pictured at left. One piece or a hundred can be produced at reasonable cost. This important development was made possible through the efforts of skilled foundrymen working with a new rammed graphite mold composition developed by Du Pont.

Sound, high-quality titanium castings are highly resistant to many corrosive environments such as hypochlorite slurries, brackish water and chlorinated organic compounds. Result: long service life, reduced downtime, lower initial and operating costs.

### PIGMENTS DEPARTMENT

REG. U. S. PAT. OFF.BETTER THINGS FOR BETTER LIVING... THROUGH CHEMISTRY

PIONEER PRODUCER OF  
**TITANIUM**

# life ... corrosion resistance ... economy in use

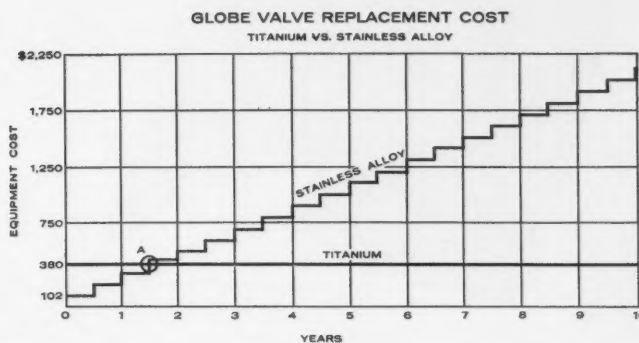
## Proven Economies

Titanium is actually the *least expensive* metal you can use under many corrosive influences. It withstands conditions that reduce the service life of ordinary and high-alloy metals ... cuts downtime and replacements.

Titanium offers the economy of long, trouble-free service when exposed to such corrosive environments as:

Salt Water  
Marine Atmospheres  
Nitric Acid  
Wet Chlorine  
Chlorinated Organic Compounds

Most Inorganic Chloride Solutions  
Molten Sulfur  
Chromic Acid  
Aqua Regia  
Hypochlorites and Chlorine Dioxide



**GREATER ECONOMIES** are now possible through use of cast titanium valves. Stainless alloy and titanium globe valves were tested in an environment of 65% nitric acid at 110° C. Stainless alloy valve cost \$102\* ... but had a *maximum* service life of only 6 months (some lasted only 3 months). The titanium valve cost \$380\*, showed no sign of corrosion after 6 months. Life expectancy: 10 years *minimum*. The \$278 difference in cost was absorbed in less than 1½ years (Point A). After 10 years, a single titanium valve will save more than \$1,750 in replacement costs alone!

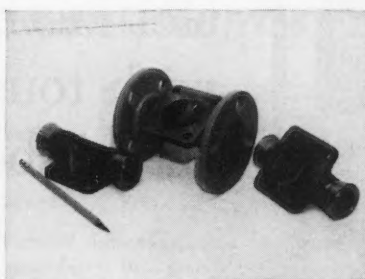
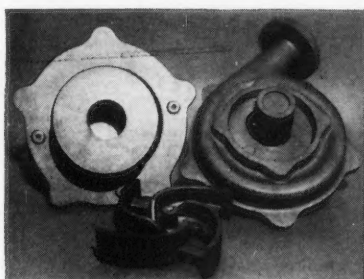
\*cost of single unit

## TITANIUM—available today

Titanium is now readily available for non-defense applications. Standard parts of titanium are already solving severe corrosion problems in the chemical, food, pulp, paper and allied industries.

In your process development work, take advantage of the corrosion and cavitation resistance, light weight, long life and high strength of titanium in continuous flow, high temperature and pressure processes.

As a manufacturer and pioneer producer of titanium sponge, Du Pont has been working with leading mill-products producers and process-equipment manufacturers on the commercial development of titanium. This broad experience can be applied to *your* process development, equipment design and plant maintenance problems. Just get in touch with Du Pont for further information about titanium—its properties and uses.



**NOW AVAILABLE**—Cast titanium parts and fitting like the centrifugal pump, diaphragm-type valve, and 5-in. IPS "Y" valve

and accessories pictured above. These are just a few examples of commercial castings made of corrosion-resistant titanium.

**MAIL COUPON TODAY** for an informative booklet about titanium—its properties and applications. E. I. du Pont de Nemours & Co. (Inc.), Pigments Department, Titanium Market Development Section, Wilmington 98, Delaware. (This offer is limited to the United States and Canada.)

E. I. du Pont de Nemours & Co. (Inc.)  
Titanium N-2420, C-8, Wilmington 98, Delaware  
Please send ☐ booklet on titanium, ☐ information on cast-titanium parts. I'm interested in titanium for the following applications: \_\_\_\_\_

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# SPONGE



*Stop damage to enamels  
from earth loads and  
soil movement...*

Johns-Manville Asbestos Wraps  
are available in 3 types for field  
application or mill wrapping.



Soil stress tests show the effective shielding action of J-M Asbestos Wraps. 18" coated sections of 4" O.D. pipe were buried in bentonite clay which was first wetted down and then allowed to dry out. At the end of 28 wetting-drying cycles, J-M Asbestos Wraps were found to give excellent protection to the enamel.

Plasticized enamel  
without J-M  
Asbestos Wrap

Plasticized enamel  
after protection with  
J-M Asbestos Wrap

**Get lasting protection  
with tough, strong  
J-M Asbestos Wraps**

Extensive research and field tests conducted by a leading firm of consulting engineers have demonstrated the effects of soil movement and earth loads on pipeline enamels. They show how the forces of the soil tend to distort and induce thin spots that weaken the protective coating... permit corrosion of the pipeline.

The same research and field tests also demonstrated that J-M Asbestos Wraps provide the strong protection that strong coatings need and deserve. "Asbestos Wraps offer the most effective single protection against damage—prolong the working life of pipeline enamels." Here's why...

Asbestos is an ageless mineral. Fibers of asbestos are strong and tough... cannot rot or decay. As used in J-M Wraps, the fibers are felted, then impregnated with a coal tar or asphalt saturant to form literally a flexible covering of stone. These "stone-like" qualities form a durable shield—

protect pipeline enamels from earth loads and soil movement which weaken coatings and permit pipe corrosion to set in.

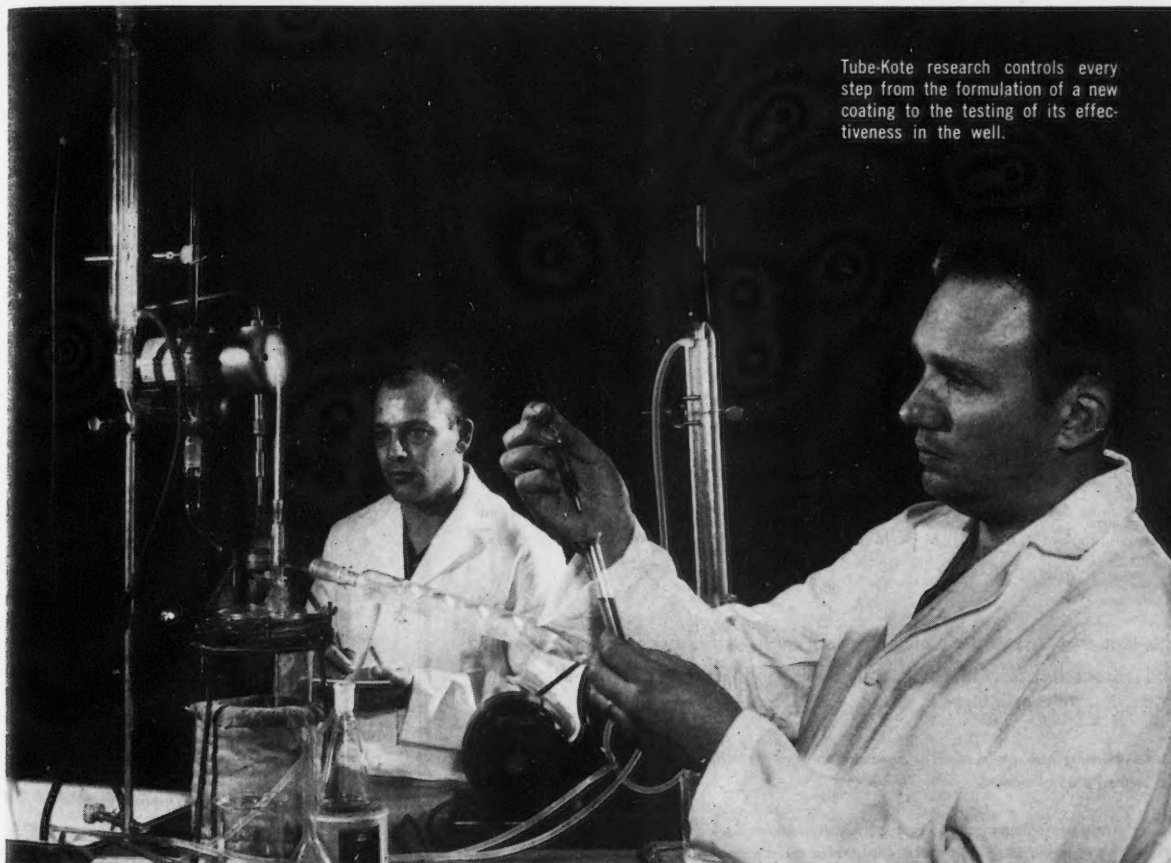
Pipeline engineers are invited to write for their own copy of PP-34A, a 3-Point Study of Pipeline Coatings and Wrappers, at no cost or obligation.

**Johns-Manville, Box 14, New York 16, N. Y.  
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Tube-Kote research controls every step from the formulation of a new coating to the testing of its effectiveness in the well.

# TUBE-KOTE®

## *Why Coatings Are Consistently Superior In Quality*

Standardization of materials used in the Tube-Kote automatic coating process is vital to maintaining desired quality. Any variation of pigment, binder or solvent will change the thickness, flow and uniformity of the coating.

Tube-Kote researchers test all materials before they are used in the plants to make certain that they meet specified standards.

Tube-Kote employs a large, full-time research laboratory to maintain quality control . . . to develop new and improved coatings . . . to solve special coating problems for customers . . . to keep Tube-Kote foremost in the industry it created almost 20 years ago.



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## Topic of the Month

# Movement of Dissolved Oxygen Through Sea Water

By E. E. NELSON,\* R. W. MOORE\* and W. J. QUINN\*

## Introduction

THE LITERATURE holds that dissolved oxygen is transported through water by diffusion and convection currents.<sup>1,2</sup> In water that is completely static the only process that occurs is diffusion. Where precautions are taken to avoid convection current, the diffusion will occur from the source of oxygen to the location where oxygen is being removed.<sup>3</sup> An example of this might be steel corroding under water where the oxygen enters the water at the surface and is depleted at the metal. In a diffusion layer there is an oxygen concentration gradient.

Where convection currents are not eliminated there usually is enough movement of water to keep the bulk of the liquid uniform with respect to dissolved oxygen. However in places where liquids contact solids there will be a thin film that is static. If oxygen is being used up by a corroding metal, it will pass through this thin film by diffusion. In unstirred water this film will be about 0.5 mm thick, although in moving water it can be much thinner.

Even in water that has no apparent motion, convection currents are believed to be much faster than diffusion. This keeps the bulk of the liquid uniform with respect to oxygen and only the diffusion layer is lower in oxygen. Common causes of convection currents are changes in temperature, vibration, air currents at the water surface, and a change in liquid density due to the corrosion reaction.

In contrast to the above theory, the practical corrosion literature often has considered that oxygen concentration gradients do occur in the bulk of the liquid. It has been stated that near the surface the water is rich in oxygen. This is supposed to provide a favorable condition for steel to become cathodic. At greater depths the water is supposed to be deficient in oxygen, where the steel would be anodic. There is no disagreement here that oxygen-rich layers are cathodic and that oxygen deficient layers are anodic for steel. But there is disagreement, however, as to how readily an oxygen concentration difference can occur in a body of water. The following experimental data were obtained to help resolve these two points of view.

## Experimental Procedure and Results

A container was provided with sampling ports as shown in Figure 1 and filled with sea water. Commercial nitrogen was bubbled through the sea water to remove the dissolved oxygen. After several hours the nitrogen was stopped and the container was left uncovered. Then samples of sea water were taken from time to time and analyzed for dissolved oxygen using a modified Winkler method. The results are shown in Table 1.

## Discussion

The results show that the oxygen concentration was uniform throughout the bulk of the sea water. If diffusion had been a factor of any significance in the movement of the oxygen, the water nearer the surface would have shown more oxygen than the lower levels. It would appear then that convection was a much more crucial factor than was diffusion.

The container was kept on a laboratory bench in a heated room with the room temperature being controlled by

an ordinary wall thermostat. It would appear that the container probably was subjected to only a few degrees of temperature change. It might be pointed out also that the building is located on a street with heavy industrial traffic that causes some vibrations.

It seems likely that many corroding systems have more liquid agitation than was present in this test. Examples of this would be outside storage tanks, ship tanks, and most water front structures. Thus, certain corrosion patterns that have been attributed to an oxygen concentration gradient in the bulk of the liquid probably would have other explanations.

## References

1. C. W. Tobias, M. Eisenberg and C. R. Wilke. Diffusion and Convection in Electrolysis—A Theoretical Review. *J. Electrochem. Soc.*, 99, 359C, (1952) Dec.
2. I. M. Kolthoff and Lingane. *Polarography*, Second Edition, Vol. 1. Interscience Publishers, New York-London, 1952, P. 19.
3. U. R. Evans and T. P. Hoar. The Velocity of Corrosion from the Electrochemical Standpoint, Part II. *Proc. Roy. Soc.*, 137A, 343, 1932.

TABLE 1—Dissolved Oxygen in Tank in PPM

TIME	TEST POSITIONS			
	1	2	3	4
Before Bubbling Nitrogen	5.9	5.8	5.8	5.9
After Bubbling Nitrogen:				
0 Hours.....	0.26	0.33	0.33	0.26
24 Hours.....	1.6	1.7	1.8	2.0
96 Hours.....	3.3	3.3	3.3	3.0
120 Hours.....	3.7	3.8	3.8	3.8
144 Hours.....	*	4.0	4.3	4.3
168 Hours.....	...	4.2	4.2	4.4
192 Hours.....	...	4.4	4.3	4.6
264 Hours.....	...	5.5	5.3	5.5

\* Water dropped below level of sampling tube due to sampling.

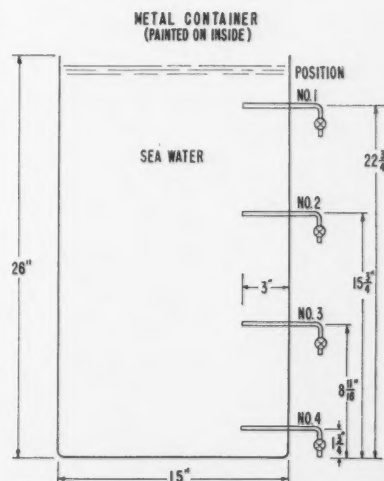


Figure 1—Vessel for determining oxygen concentration gradients in the bulk of a liquid.

\* Socony Mobil Oil Company, Inc., Brooklyn, New York.

# Corrosion Rates in Port Hueneme Harbor\*

By CARL V. BROUILLETTE

## Introduction

THE CHOICE of a particular metal for use in a marine environment is influenced by its rate of corrosion in that environment. Ocean harbors differ widely in their corrosiveness toward a metal because of such factors as salt content, pollution, rate of flow, wave action, sand or silt content, temperature, and marine growth.

In 1950 the Bureau of Yards and Docks of the Navy Department established the Naval Civil Engineering Research and Evaluation Laboratory at Port Hueneme, California. Thus it was necessary to determine the corrosiveness of the harbor water at Port Hueneme to various construction metals.

## Description of Test

Sixteen different metals and alloys were immersed in the harbor approximately two feet below the mean low water level. The specimens were cut from metal sheets to a size of 12 by 12 inches. The specimens were cut by use of a metal saw in an attempt to prevent cold-working the edges, and thus minimize the amount of electrochemical corrosion. The thickness of the metal sheets varied from .103 to .206 inch.

Five identical test panels of each metal were immersed at the same time. The panels were supported on racks\* of stainless steel by porcelain insulators. One panel of each type of metal was examined after each six-month period and the degree of corrosion determined as weight loss. These losses were calculated to a uniform-loss basis as mils per

About  
the  
Author



CARL V. BROUILLETTE has been with the U. S. Naval Civil Engineering Research and Evaluation Laboratory for more than seven years. He is a Project Engineer in the Chemistry Division, which studies protective coatings and corrosion mitigation. Mr. Brouillette received an AB degree from William Jewell College and a MA degree from the University of Kansas City and did graduate work in chemistry at Purdue University. He is a member of the National Association of Corrosion Engineers and the American Chemical Society. Prior to his employment at NAVCERLAB, he worked in the fields of analytical chemistry and organic synthesis. He served in the amphibious forces of the Navy during the last war.

year (mpy) and milligrams per square decimeter per day (mdd). Since pitting is a major factor in corrosion loss for some of the metals exposed at Port Hueneme, the maximum and average pit depths also were determined by using a penetrometer with a needle point. Small pin points were not included in this average.

The temperature of the harbor water varied from 58 F to 64 F, the salinity

## Abstract

The corrosion rates of 16 metals and alloys were determined over a period of 30 months total immersion in the sea water at Port Hueneme, California. Lead evidenced the least attack while the magnesium alloys were the most readily attacked. The corrosion rates in the harbor at Port Hueneme appear to be typical of the sea water along the California coast, aggravated to some extent by marine growth. Pitting was a major factor in the corrosion of aluminum, stainless steel, and Monel. 2.2.7

from 2.8 percent to 3.2 percent, and the pH from 7.9 to 8.2. The range of these variations is so small that a relatively constant environment may be assumed.

The maximum velocity of the water in the area of the immersed test panels was calculated to be 0.2 feet per second, and decreased to approximately zero during tide changes.

Toward the latter stages of the test period, marine growth began to form on the panels. Barnacles appeared to accelerate pitting on certain metal specimens.

One of each of the 16 metal specimens was removed from the water at the end of each six-month interval and cleaned by wire brushing to remove marine growth. They were then electrolytically cleaned except for the magnesium alloys which received only a wire brushing. The specimens were weighed, examined for pit depth, and photographed.

The metal, nominal composition and Federal specification number are listed for each of the 16 metals in the tables. The corrosion losses are given in mdd in Table 1 and in mpy in Table 2. Table 3 gives the pitting data.

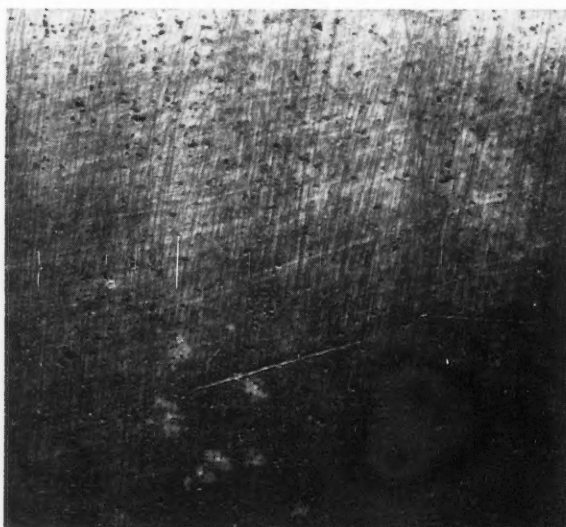


Figure 1—Profuse pitting of 1100 aluminum.

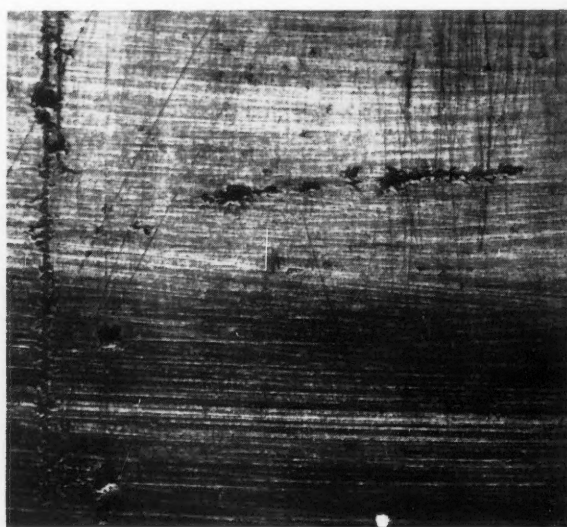


Figure 2—Deep pits at scratches in the oxide coating of 3003 aluminum.

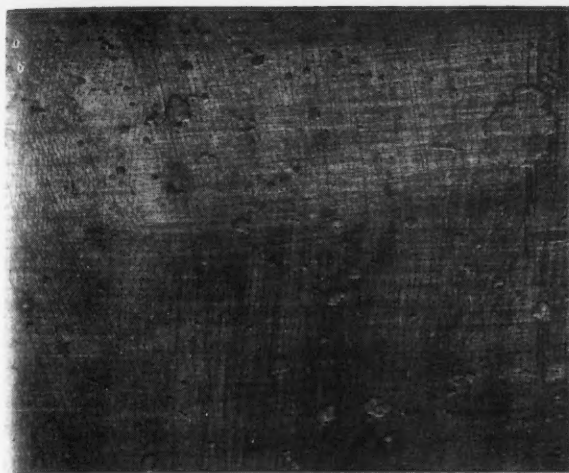


Figure 3—Shallow pitting of 2024 aluminum clad.

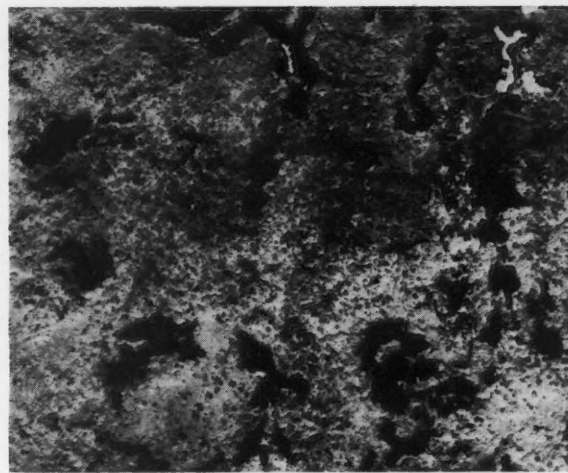


Figure 4—Magnesium alloy (AZ 31B) after six months exposure.

TABLE 1—Corrosion Rates in MDD

Metal	Nominal Composition	Temper	Government Specification Number	CORROSION LOSS—MDD				
				6 Mos.	12 Mos.	18 Mos.	24 Mos.	30 Mos.
Aluminum Alloy (1100)	Al = 99.0% Si + Fe = 0.8%	O	QQ-A-561	2.1	1.9	1.3	1.0	0.9
Aluminum Alloy (3003)	Al = 97.4%, Si = 0.5% Mn = 1.3%, Fe = 0.6%	H24	QQ-A-359	3.4	2.5	1.7	1.4	1.3
Aluminum Alloy (5052)	Al = 96.6% Mg = 2.5%	H22	QQ-A-318	1.0	(1)	(1)	(1)	0.4(3)
Aluminum Alloy, Clad (2024)	Core: Al = 92.4%, Mn = 0.6% Cu = 4.4%, Si = 0.4% Mg = 1.5%, Fe = 0.4% Cladding: Al = 99.3%, Si + Fe = 0.6%	T3	QQ-A-362	0.8	1.2	0.6	0.8	(1)
Magnesium Alloy (AZ 31B)	Mg = 95.2% Al = 5.5% Zn = 1.0%	O	QQ-M-44	(4)	(4)	(2)		
Magnesium Alloy (AZ 31B)	Mg = 95.2%, Al = 3.0% Zn = 1.0%	H24	QQ-M-44	(4)	(4)	(2)		
Magnesium Alloy (M1A)	Mg = 98.2% Mn = 1.2%	O	QQ-M-54	25.2	(4)	(4)	(2)	
Bronze, Aluminum	Cu = 94.0, Fe = 0.4%	Soft	QQ-B-667 Composition 3	4.0	2.5	1.9	1.3	1.9(3)
Bronze, Phosphor	Cu = 94.8%, P = 0.2% Sn = 4.7%	No. 4 Hard	QQ-P-330 Composition A	4.6	3.7	3.2	3.1	2.8
Bronze, Manganese	Cu = 58.5%, Sn = 1.0% Zn = 38.4%, Mn = 0.3% Fe = 1.4%	Hard	QQ-M-80 Class A	5.5	6.4	6.4	5.7	6.4
Brass, Naval	Cu = 61.0%, Sn = 0.8% Zn = 38.0%	Soft	MIL-N-994	7.6	6.5	7.1	5.9	(1)
Monel	Ni = 66.5%, Mn = 1.0% Cu = 29.4%, Al = 0.4% Fe = 2.0%, Si = 0.4%	Annealed	QQ-N-281 Class A	6.1	3.1	2.6	2.9	(1)
Copper, Electrolytic	Cu = 99.9%	Soft	QQ-C-576	4.4	4.0	3.7	3.4	(1)
Lead	Pb = 99.5%		QQ-L-201 Grade B	1.4	1.5	1.0	1.1	1.7
Steel, Stainless	Cr = 18.0%, Si = 0.8% Ni = 8.0%, Cu = 0.4% Mn = 1.6%, C = 0.08%	Annealed	MIL-S-854 Class 1	6.6	2.5	2.3	1.5	1.2(3)
Steel, Low Carbon			QQ-S-695	41.2	40.0	27.4	31.8	45.5

(1) Rack failure; metal panel lost.

(2) Excessive corrosion caused loss of metal panel.

(3) Found by salvage diver after 30-months' exposure

(4) Large holes corroded through the metal panel.

### Discussion

Corrosion losses were calculated to uniform surface corrosion in mils per year (mpy) and milligrams per square decimeter per day (mdd), from the weight loss after each six-month inspection period. The corrosion losses over the surface of copper base metals, lead,

and the stainless steel, were mild and uniform. Stainless steel showed attack in the form of elongated pits starting at the edges and progressed between the plate surfaces, eventually penetrating one surface. Pitting on Monel was attributed primarily to marine growth. Corrosion on aluminum specimens was

mostly in the form of pitting. When calculated to mpy and mdd, this gives corrosion losses which appear less severe than the pitting penetration figures indicate.

Under conditions which prevailed in the Port Hueneme harbor during the 30-month duration of this experiment, lead sheet (99.5 percent pure) suffered the least attack by corrosion. Magnesium alloy was most readily attacked, and, by the end of the first six months, holes were corroded through the 0.1945 inch thick metal specimen.

Various factors, such as kelp, wave action, and damage to the corrosion racks, caused a loss of several specimens to the harbor floor. In some instances a diver was able to locate the specimen, and it was included in the series to which it belonged.

#### (1) Aluminum, (1100) QQ-A-561, Temper O

Corrosion attack on this material produced many deep pits which grew progressively deeper with time.

Apparently they started with breaks in the oxide coating on the surface of the panel. The major pits at the end of six months averaged 19.0 mils in depth and grew in depth at approximately 10 mils per year for the next two years (see Figure 1).

#### (2) Aluminum, (3003) QQ-A-359, Temper H24

Corrosion occurs here in the form of pitting. The pits appear to increase in size and depth rather than in number as time of exposure is increased. Pits appeared at the break in the oxide coating on the surface of the panel which exposed anodic areas. These pits grew to a maximum depth of 70.0 mils in 30 months. At the end of six months the pits averaged 37.4 mils and grew in depth at the rate of approximately 20.0 mils per year for the next two years. Note in Figure 2 how corrosion followed scratch lines through the aluminum oxide coating.

#### (3) Aluminum, (5052) QQ-A-318, Temper H22

At the end of six months, corrosion appeared on this material as numerous pits approximately 5.0 mils in depth. A diver salvaged the 30-month specimen from the harbor floor. This panel showed very little increase in size of pits except for several large pits, approxi-



mately 35 mils in depth, which may have been caused by galvanic action with other metallic objects on the harbor floor. The results from these two panels indicate this alloy has good corrosion resistance; however, the environmental conditions of the panel salvaged from the harbor floor with relation to other panels in this series are unknown.

(4) *Aluminum, Clad (2024) QQ-A-362, Temper T3*

This aluminum showed the least corrosion of the four kinds tested. The pits which formed appeared to increase in area rather than depth. The average depth to which the corrosion penetrated the aluminum-clad alloy by the end of one year was 4.0 mils and by the end of two years was 6.5 mils. The attack penetrated only very slightly beyond the metallurgically bonded anodic aluminum coating during the 30 months test (see Figure 3).

(5) *Magnesium Alloy (AZ 31B)<sup>(1)</sup> QQ-M-44, Temper 0*

At the end of only six months, holes were corroded completely through this metal panel. By the end of one year the panels had decreased in size so that they fell from the corrosion racks and were lost. The specimens after six months are shown in Figure 4.

(6) *Magnesium Alloy (AZ 31B)<sup>(1)</sup> QQ-M-44, Temper H24*

These results are similar to those for alloy (5) above.

(7) *Magnesium Alloy (M1A)<sup>(2)</sup> QQ-M-54, Temper 0*

At the end of six months severe overall surface corrosion was evident. After one year large holes had been corroded through the panel, and after 18 months the panels fell from the racks and were lost. This alloy had slightly better corrosion resistance than the alloys (5) or (6).

(8) *Bronze, Aluminum (Cu 94.0%, Al 5.5%) QQ-B-667, Composition 3, Temper Soft*

The surface of all five panels showed only a very slight, smooth form of surface attack which was not localized. This alloy corroded the least of the copper base alloys, including electrolytic copper.

(9) *Bronze, Phosphor (Cu 94.8%, Sn 4.7%) QQ-P-330, Composition A, Temper No. 4 Hard*

Corrosion attack was very mild, with very slight attack near the edges. This alloy appeared equal to aluminum bronze in corrosion resistance to sea water.

(10) *Bronze, Manganese (Cu 58.5%, Zn 38.4%) QQ-M-80, Class A, Temper Hard*

Corrosion was very mild and uniform, although it evidenced twice the corrosion loss shown by aluminum bronze or phosphor bronze.

(11) *Brass, Naval (Cu 61.0%, Zn 38.0%) MIL-N-994, Temper Soft*

The corrosion was very slight and at a uniform rate, with no apparent pitting. This alloy appears comparable to manganese bronze in corrosion resistance to sea water.

<sup>(1)</sup> Mg 95.2%, Al 3.0%, Zn 1.0%.  
<sup>(2)</sup> Mg 98.2%, Mn 1.2%.

TABLE 2—Corrosion Rates in MPY

Metal	Nominal Composition	Temper	Government Specification Number	CORROSION LOSS—MPY				
				6 Mos.	12 Mos.	18 Mos.	24 Mos.	30 Mos.
Aluminum Alloy (1100)	Al—99.0% Si & Fe—0.8%	O	QQ-A-561	1.1	1.0	0.7	0.6	0.5
Aluminum Alloy (3003)	Al—97.4%, Fe—0.6% Mn—1.3%, Si—0.5%	H24	QQ-A-359	1.8	1.3	0.9	0.8	0.7
Aluminum Alloy (5052)	Al—96.6%, Mg—2.5%	H22	QQ-A-318	0.6	(1)	(1)	(1)	0.2(1)
Aluminum Alloy, Clad (2024)	Core: Al—92.4%, Mn—0.6%, Cu—4.4%, Si—0.4%, Mg—1.3%, Fe—0.4% Cladding: Al—99.3%, Si & Fe—0.6%	T3	QQ-A-362	0.4	0.6	0.3	0.4	(1)
Magnesium Alloy (AZ 31B)	Mg—95.2%, Al—3.0%, Zn—1.0%	O	QQ-M-44	(4)	(4)	(2)		
Magnesium Alloy (AZ 31B)	Mg—95.2%, Al—3.0%, Zn—1.0%	H24	QQ-M-44	(4)	(4)	(2)		
Magnesium Alloy (M1A)	Mg—98.2%, Mn—1.2%	O	QQ-M-54	20.8	(4)	(4)	(2)	
Bronze, Aluminum	Cu—94.0%, Fe—0.4%, Al—5.5%	Soft	QQ-B-667 Composition 3	0.7	0.4	0.3	0.2	0.3(1)
Bronze, Phosphor	Cu—94.8%, P—0.2%, Sn—4.7%	No. 4 Hard	QQ-P-330 Composition A	0.7	0.6	0.5	0.5	0.5
Bronze, Manganese	Cu—58.5%, Sn—1.0%, Zn—38.4%, Mn—0.3%, Fe—1.4%	Hard	QQ-M-30 Class A	0.9	1.1	1.1	1.0	1.1
Brass, Naval	Cu—61.0%, Sn—0.8%, Zn—38.0%	Soft	MIL-N-994	1.3	1.1	1.2	1.0	(1)
Monel	Ni—66.5%, Mn—1.0%, Cu—29.4%, Al—0.4%, Fe—2.0%, Si—0.4%	Annealed	QQ-N-281 Class A	1.0	0.5	0.4	0.5	(1)
Copper, Electrolytic	Cu—99.9%	Soft	QQ-C-576	0.7	0.7	0.6	0.6	(1)
Lead	Pb—99.5%		QQ-L-201 Grade B	0.2	0.2	0.1	0.1	0.2
Steel, Stainless	Cr—18.0%, Si—0.8%, Ni—8.0%, Cu—0.4%, Mn—1.6%, C—0.08%	Annealed	MIL-S-854 Class 1	1.2	0.5	0.4	0.3	0.2(3)
Steel, Low Carbon			QQ-S-695	7.5	7.3	5.0	5.8	8.3

(1) Rack failure; metal panel lost.

(2) Excessive corrosion caused loss of metal panel.

(3) Found by salvage diver after 30 months' exposure.

(4) Large holes corroded through the metal panel.

(12) *Monel (Ni 66.5%, Cu 29.4%) QQ-N-281, Class A, Annealed*

Corrosion attack mostly was in the form of pits which appeared beneath fouling organisms. Except for these pits (which grew progressively deeper) the surface remained smooth and apparently free from attack. By the end of 24 months these pits beneath the marine organisms were between 10 and 37 mils in depth. Marine organisms appeared to have caused localized oxygen concentration cells, which in turn cause pitting, especially beneath barnacles (see Figure 5).

(13) *Copper, Electrolytic (Cu 99.9%) QQ-C-576, Temper Soft*

During the corrosion test period, only an occasional small pit was found in these five copper panels. Corrosion losses were confined almost entirely to the edges. This type of corrosion indicated differences in temper of the two sides of the metal edge. Although a saw was used to cut these panels, temper differences apparently were introduced. Where slight potential differences exist, the harder portion is corroded preferentially.

(14) *Lead (Pb 99.5%) QQ-L-201, Grade B*

Corrosion attack on the lead was very mild and uniform, with no pitting in evidence. Lead showed the least attack of the 16 metals tested.

(15) *Steel, Stainless (18% Cr, 8% Ni, 0.08% maximum C) MIL-S-854—Class 1, Cold-Rolled, Annealed*

Corrosion of the stainless steel (18-8) was in the form of elongated pits running from the top edge downward (in a few instances from the bottom upward). These elongated pits often ran partly below the surface and penetrated through to the side of the metal panel (see Figure 6). At the end of 24 months exposure of total immersion in sea water, one elongated pit had reached the length of three and one-quarter inches. The 30-month panel salvaged from the harbor floor showed the least attack of the five panels.

(16) *Steel, Low Carbon—QQ-S-695, Pickled, Full Cold-Rolled*

Corrosion attack on the steel panel was general, with some pitting. The 6.8 mpy (37.2 mdd) corrosion loss for mild steel shown by this study is similar to that reported for this general area.<sup>4</sup>

### Summary

#### 1. Aluminum

The aluminum clad (2024) appeared to suffer the least amount of corrosion attack of the aluminum group of metals studied. The clad coating of aluminum is anodic to the aluminum alloy underneath; thus, deep pitting was prevented by cathodic protection. On the alumi-

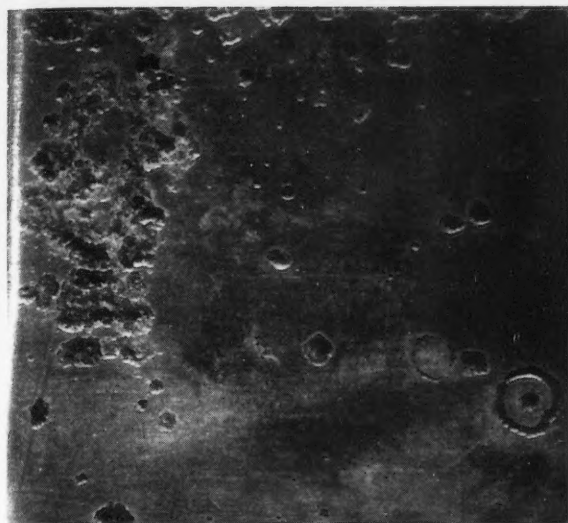


Figure 5—Pitting beneath marine growth on Monel.



Figure 6—Elongated pitting on 18-8 stainless steel.

TABLE 3—Depth of Pits

Metal	Nominal Composition	DEPTH OF PITS IN MILS									
		6 Months		12 Months		18 Months		24 Months		30 Months	
		Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.
Aluminum Alloy (1100).....	Al—99.0%, Si & Fe 0.8%	22.0	19.0	32.0	27.0	46.2	33.2	54.0	52.6	70.0	43.8
Aluminum Alloy (3003).....	Al—97.4% Si—0.5%, Mn—1.3%, Fe—0.6%	48.0	37.4	50.0	42.2	70.8	56.9	84.5	67.2	70.0	52.0
Aluminum Alloy (5052).....	Al—96.6%, Mg—2.5%		5.0	(1)		(1)		(1)		(3)*	*34.7
Aluminum Alloy, Clad (2024)...	Core: Al—92.4%, Cu—4.4%, Mg—1.5%, Mn—0.6%, Si—0.4%, Fe—0.4%, Cladding: Al—99.3%, Si & Fe—0.6%	(a)		4.0	3.9	4.9	3.5	6.5	4.4	(1)	
Magnesium Alloy (AZ 31B) 0	Mg—95.2%, Al—3.0%, Zn—1.0%	(b)		(b)		(2)				complete loss	
Magnesium Alloy (AZ 31B) H24	Mg—95.2%, Al—3.0%, Zn—1.0%	(b)		(b)		(2)				complete loss	
Magnesium Alloy (M1A).....	Mg—98.2%, Mn—1.2%	(c)		(b)		(b)		(2)		complete loss	
Bronze, Aluminum.....	Cu—94.0%, Fe—0.4%, Al—5.5%	(d)		(d)		(d)		(d)		(d) (3)	
Bronze, Phosphor.....	Cu—94.8%, P—0.2%, Sn—4.7%	(d)		(d)		(d)		(d)		(d)	
Bronze, Manganese.....	Cu—58.5%, Sn—1.0%, Zn—38.4%, Mn—0.3%, Fe—1.4%	(d)		(d)		(d)		(d)		(d)	
Brass, Naval.....	Cu—61.0%, Sn—0.8%, Zn—38.0%	(d)		(d)		(d)		(d)		(1)	
Monel.....	Ni—66.5%, Mn—1.0%, Cu—29.4%, Al—0.4%, Fe—2.0%, Si—0.4%	20.0	10.0	17.0	13.8	22.5	15.0	37.0	32.0	(1)	
Copper, Electrolytic.....	Cu—99.9%	(d) (f)		(d) (f)		(d) (f)		(d) (f)		(1)	
Lead.....	Pb—99.5%	(d)		(d)		(d)		(d)		(d)	
Steel, Stainless.....	Cr—18.0%, Si—0.8%, Ni—8.0%, Cu—0.4%, Mn—1.6%, C—0.08%	(e)		(e)		(e)		(e)		(e) (3)	
Steel, Low Carbon.....		(c)		(c)		(c)		(c)		(c)	

\* See text.

(a) Fine pin-point pitting covering panel surface.

(b) Holes corroded through metal panels.

(c) Overall pitting; continuous surface corrosion.

(d) No noticeable pitting.

(e) Elongated pits running vertically across panel.

(f) Corrosion confined to edges.

(1) Rack failure; metal panel lost.

(2) Excessive corrosion caused loss of metal panels.

(3) Found by salvage diver after 30 months exposure.

num specimens containing no anodic-clad coating, a cathodic oxide film formed. This film gave good protection except at pin hole openings or scratches which exposed the anodic core metal. Pitting progressed rapidly at these places because of the large cathodic area compared to the small exposed anodic area.

## 2. Magnesium

Magnesium metals corroded so rapidly that discussion is not warranted.

## 3. Brass and Bronze

The aluminum bronze and phosphor bronze corroded very slightly and in a uniform manner with no pitting. The corrosion loss was about 0.5 mpy (3.1 mdd). The manganese bronze and the Naval brass corroded only slightly and with no pitting; their corrosion losses were about 1.1 mpy (6.4 mdd) or double that of the aluminum and phosphor bronzes. These metals appear very serviceable in the Port Hueneme harbor water.

## 4. Monel

Monel metal evidenced considerable pitting, especially under marine growth. Reference 1 indicates that, where marine organisms accumulate, pitting may result from localized oxygen concentration cells formed on the surface of the metal. Photographs of the Monel panels show the results of pitting formed beneath marine organisms.

## 5. Copper

During the 30-month underwater ex-

posure, copper corrosion was confined almost entirely to the edges and was attributed to the differences in temper at the edge caused by cutting the panels from sheet stock. Very little attack occurred on the flat surfaces of the panels.

#### 6. Lead

Lead evidenced the least attack by corrosion during the 30-month underwater exposure in the Port Hueneme harbor.

#### 7. Stainless Steel

Stainless steel evidenced attack by corrosion in the formation of elongated pits. These pits were typical of 18-8 stainless steel panels placed in complete immersion in slow-moving or stagnant sea water. Reference 1 indicates that in

this type of pitting, the anodic products (iron and other metal chlorides) apparently concentrate inside the pit as it forms. These acidic concentrated solutions destroy the passivity of the stainless steel, enlarging the pit, as they flow down the panel. The literature recommends 2-4 percent molybdenum to lessen the corrosion attack by pitting.<sup>1</sup>

#### 8. Low Carbon Steel

Low carbon steel, according to reference 1, has a range of corrosion rates from 1 to 27 mpy (5.5-42.4 mdd) when exposed continuously in sea water. Thus, the harbor water at Port Hueneme attacks low carbon steel at a rapid rate, the average for 30-month exposure being 6.8 mpy (37.2 mdd) with initial rates as high as 7.5 mpy (41.2 mdd).

#### 9. General

The rate of corrosion in the harbor at Port Hueneme appears to be typical of sea water along the California coast, aggravated to some extent by marine growth. In spite of the fact that the average rate of flow past the panel exposure area is low (the maximum rate calculated to be approximately 0.2 feet per second), there appears to be no unusual corrosion phenomena. Pitting losses were a major factor for aluminum, stainless steel, and Monel. There were no evidences of harbor pollution.

#### Reference

1. Herbert H. Uhlig (Editor), *The Corrosion Handbook*, John Wiley and Sons, Inc., New York, 1948.

**Any discussions of this article not published above  
will appear in the December, 1958 issue**

### DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

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# Corrosion Problems in the Manufacture Of Phosphoric Acid From Elemental Phosphorus\*

By J. C. BARBER

## Introduction

PHOSPHORIC ACID is produced commercially by two processes—the wet process and the electric-furnace process. Wet process acid is made by reacting pulverized phosphate ore with sulfuric acid to form calcium sulfate and dilute phosphoric acid. The insoluble calcium sulfate and other solids in the acid are removed by filtration. The dilute phosphoric acid (32 percent  $P_2O_5$ ) may then be concentrated in evaporators (to acid containing about 55 percent  $P_2O_5$ ).

In the electric-furnace process elemental phosphorus is first produced from phosphate ore, coke, and silica in an electric furnace; then the elemental phosphorus is burned with air to form  $P_2O_5$  which is reacted with water to form  $H_3PO_4$ . The acid normally produced by this method contains 55 to 60 percent  $P_2O_5$  and further concentration is unnecessary for most uses. Figures 1 and 2 are simplified diagrams of the two methods of producing the acid.

The amounts of phosphoric acid produced by both the wet and the electric-furnace processes have increased significantly during the past few years. In 1950, total phosphoric acid production amounted to 594,000 tons of  $P_2O_5$ , 48 percent of which was produced by the electric-furnace process. By 1956 the total production had more than doubled. At that time it amounted to 1,291,000 tons of  $P_2O_5$  of which 44 percent was produced by the electric-furnace process.

The consumption of phosphoric acid is closely related to the markets for soaps, detergents, and food supplements. Thus the production rate of this acid would be expected to increase in proportion to population increases, if no new uses were found.<sup>1</sup> Actually though, new markets are being developed and there is a trend toward the use of greater amounts of concentrated fertilizers (such as triple superphosphate) which use phosphoric acid. Presently, work is being carried out at TVA to develop new fertilizers by the use of a highly concentrated phosphoric acid (containing 76 percent  $P_2O_5$ ) which can be produced by the electric-furnace process.<sup>2</sup>

Phosphoric acid made by the wet process costs less than that made by the electric-furnace process. However, the former contains more impurities, such as iron and calcium salts, sulfuric acid, and fluorine compounds. In many fertilizer processes involving the use of phosphoric acid, a large amount of impurities can be tolerated. For most other industrial uses, however, the acid must be purified and the removal of large amounts of impurities eliminates the cost



About  
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advantage for the wet process acid. Consequently, about 80 percent of the wet-process acid is used for the production of fertilizers.<sup>3</sup> Electric-furnace process acid is consumed mainly in the production of soaps, detergents, feed-grade dicalcium phosphate, ammonium and potassium phosphates, and food chemicals. Electric-furnace process acid also is used in the preparation of liquid fertilizer mixtures because large amounts of impurities are objectionable in these mixtures.

Phosphoric acid is a highly reactive chemical and this necessitates the use of special materials of construction for the production facilities. The production of phosphoric acid from elemental phosphorus involves high temperatures which greatly increase the corrosion of the equipment. In both the wet-process and the electric-furnace process, impurities cause both corrosion and erosion to be increased. For these reasons phosphoric acid plant operators are constantly looking for new materials of construction and improved operating techniques which will minimize their corrosion problems and thereby reduce their operating costs.

Published literature on the corrosion rates of various materials exposed to phosphoric acid is helpful in choosing materials of construction and in determining the conditions under which plant equipment can be operated without excessive corrosion. However, these rates are generally based on tests carried out under closely controlled conditions which will yield reproducible results. And frequently plant operating conditions are more severe than those encountered during the tests. Factors such as impurities in the process materials, localized high temperatures, and com-

## Abstract

The principal materials used in the construction of equipment for the manufacture of phosphoric acid (55-60 percent  $P_2O_5$ ) from elemental phosphorus are described in this paper. This process involves the combustion of phosphorus to form  $P_2O_5$  which is then reacted with water to form the acid. The general application of various metals, ceramics, and plastics in the construction of the processing equipment are discussed. The high temperatures characteristic of the process, as well as the impurities in the phosphorus burned, accelerate corrosion in parts of the system. Mist and impurities in the gas stream also cause some erosion. Methods of coping with these problems have been derived from large-scale tests and from plant operating experience.

A highly concentrated phosphoric acid (containing 76 percent  $P_2O_5$ ) also can be made in the regular equipment. The corrosion problems incurred in the production of this acid are discussed.

Typical operating data are given for a phosphoric acid production unit. Other data reported include corrosion rates of Type 316 stainless steel exposed to phosphoric acid at various temperatures and corrosion rates of this material in a Venturi scrubber. Relative corrosion rates of 11 metals are computed with respect to Type 316 stainless steel. 8.8.1

binations of corrosive and erosive conditions may cause unexpected plant corrosion problems. Information on the service life and maintenance of plant equipment, and corrosion results obtained under plant operating conditions, can be used to supplement the corrosion data obtained in the laboratory under closely controlled conditions. This paper describes the exposure conditions and gives corrosion results obtained in a plant for the production of phosphoric acid from elemental phosphorus.

## Production of Phosphoric Acid From Elemental Phosphorus

For the production of phosphoric acid from elemental phosphorus the liquid phosphorus is atomized by compressed air or steam in a burner and secondary air is added to complete the combustion of phosphorus. The combustion chamber is usually constructed of water-cooled graphite blocks cemented together with a resin base cement. This type of construction generally has been found to be best for the combination of high-temperatures and corrosive conditions; however, stainless steel also has been used successfully for the construction of the combustion chamber and hydrator.<sup>3</sup> Graphite block combustion chambers involve expensive construction methods, and it is difficult to prevent in-leakage of some of the cooling water. One design used in an attempt to overcome these problems involved constructing the combustion chamber in the form of a "quonset hut" with a phosphorus burner at each end.<sup>3</sup>

In the hydrator the gases are cooled by spraying them with water or weak phosphoric acid, and carbon blocks or water-cooled stainless steel are used as the material of construction. Most of

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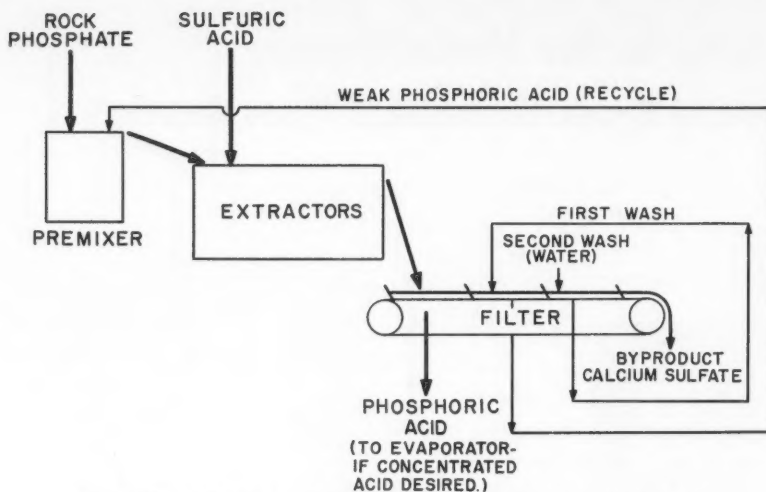


Figure 1—General flow diagram of the wet process for the manufacture of phosphoric acid.

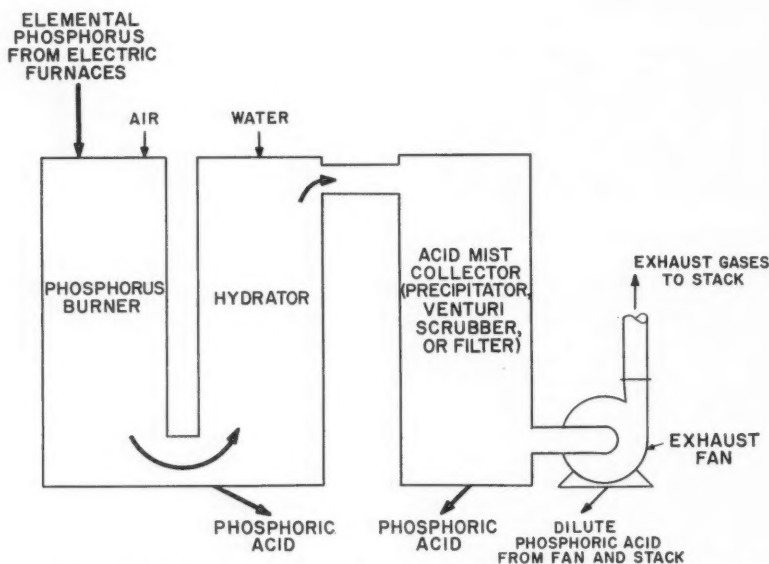


Figure 2—General flow diagram of the electric furnace process for the manufacture of phosphoric acid.

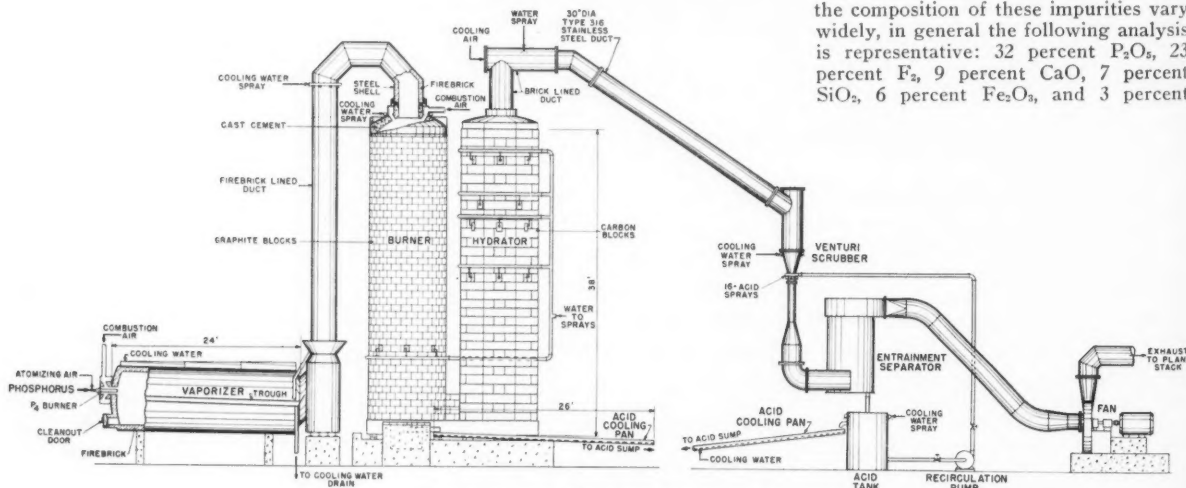


Figure 3—Diagram of No. 1 phosphoric acid plant.

the acid is recovered in the hydrator, but some of it leaves this unit in the gas stream as small droplets or mist, so equipment must be provided for the recovery of the acid in this form. Electrostatic precipitators, packed towers, Venturi scrubbers, and glass wool filters have been employed to remove acid from the gas leaving the hydrator. Metals or ceramics are used for constructing the gas cleaning equipment. The exhaust gases are discharged through metal fans and ducts to a ceramic stack.

Some of the work done at TVA on the development of processes for production of phosphoric acid already has been described.<sup>4,5,6</sup> Since those reports were made, however, further modifications have been made to some of the equipment. A diagram of the equipment presently used at the No. 1 acid plant is shown in Figure 3.

#### Burning of Phosphorus and Phosphorus Sludge

Liquid phosphorus is injected into one end of a horizontal, cylindrical chamber called a vaporizer. Compressed air is used to atomize the phosphorus and sufficient combustion air from a fan is introduced into the vaporizer to burn about 20 percent of the phosphorus. The unburned phosphorus is vaporized and solids originally contained in the phosphorus are left in the vaporizer as a fused mass, called vaporizer slag. The vaporizer slag is removed periodically by allowing it to drain out through a cleanout door. The vaporizer has a 3/8-inch steel shell, which is lined inside with firebrick. The outside surface of the vaporizer is water-cooled.

Two types of phosphorus are produced by the electric-furnace method: one contains a small amount of impurities (about 0.5 percent) and the other contains a larger amount (15 to 20 percent). The product containing the smaller percentage of impurities is called phosphorus and the less pure material, comprising about 25 to 30 percent of the total phosphorus produced, is called phosphorus sludge. The impurities in the phosphorus and phosphorus sludge consist mainly of solids carried out in the gas stream from the phosphorus furnaces as dust or volatilized materials. Although the composition of these impurities vary widely, in general the following analysis is representative: 32 percent  $P_2O_5$ , 23 percent  $F_2$ , 9 percent  $CaO$ , 7 percent  $SiO_2$ , 6 percent  $Fe_2O_3$ , and 3 percent

$\text{Al}_2\text{O}_3$ . Other constituents are  $\text{K}_2\text{O}$  and  $\text{Na}_2\text{O}$ . Since the vaporizer provides a means for separating most of these solid impurities from the phosphorus, either phosphorus or phosphorus sludge can be burned in the No. 1 acid plant.

Temperatures of the vaporizer outlet gas are usually in the range of 1600-1800 F. These temperatures are controlled by the amounts of combustion air and phosphorus (or phosphorus sludge) added to the vaporizer. Sometimes the vaporizer outlet gas temperature is increased to the range of 1800-2000 F for short periods to melt the vaporizer slag so that it will drain readily.

The gases from the vaporizer flow through a firebrick-lined, water-cooled steel duct to the top of the vertical combustion chamber where sufficient air is added to complete the combustion. The combustion chamber is called a burner; it is constructed of graphite blocks with furan-base cement joints. Cooling water flows over the outside in order to keep the graphite blocks cool and prevent their oxidation. The water cooling keeps the inside surface of the graphite within the range of 400-600 F—well below the temperature at which graphite begins to oxidize (about 750 F). Internal water sprays are located about 10 feet from the bottom of the burner to cool the gases before they enter the hydrator. Phosphorus or phosphorus sludge burning rates are adjusted so that the burner outlet gas temperature is in the range of 850 to 1050 F.

#### Hydration of the $\text{P}_2\text{O}_5$ and Collection of the Acid

The hydrator is an octagonal-shaped tower 38 feet high, and the distance between opposite sides is 8 feet 4 inches. It is constructed of carbon blocks which also are cemented together with a furan-base cement. Internal water sprays are located at four different levels in the hydrator. Spray nozzles are added or removed from the hydrator in order to control the acid concentration.

Acid collected in the burner and hydrator flows out through a single opening located at the bottom of the burner. The acid flows over a pan-type cooler which is an open channel of rectangular cross-section. This channel contains a jacketed bottom through which cooling water flows beneath the hot acid. The cooler is 30 inches wide and 26 feet long and it is fabricated from No. 10 gage Type 316 stainless steel. During normal

operation the acid is cooled from 325 to 180 F.

Gases leaving the hydrator flow through a brick-lined, mild steel duct where they are further cooled by a water spray. Cooling air (about 5,000 cubic feet per minute STP) also is admitted to the gas stream. An unlined, Type 316 stainless steel duct about 63 feet long connects the brick-lined duct to a Venturi scrubber.

#### Recovery of Acid Mist and Exhaustion of Gases

The Venturi scrubber, which was installed in July 1954, replaced an electrostatic precipitator that had been used previously to collect entrained acid mist from the gas stream.<sup>4</sup> The scrubber proper is 14 feet 6 inches high and 30 inches in diameter at the inlet and outlet. There is a restricted section, called a throat, which has a minimum diameter of 11½ inches. The scrubber assembly, including the ducts, pumps, acid piping, and exhaust fan is fabricated from ¾-inch thick Type 316 stainless steel. Gas temperatures within the scrubber must not be allowed to exceed 225 F in order to prevent excessive corrosion of the stainless steel. The outside surfaces of the gas duct and the scrubber are water-cooled whenever necessary to lower the gas temperature.

Within the Venturi scrubber the gases pass through the throat. Here sixteen ¼-inch diameter jets spray acid droplets into the gases. Acid mist particles collect on these droplets by impaction and diffusion, after which the droplets are collected in a cyclone type of entrainment collector. The gas velocity at the throat is about 230 feet per second. Gases from the scrubber enter the entrainment separator tangentially at the bottom and leave at the top. Acid collected in the entrainment separator drains to a tank from which part of it is recycled to the Venturi throat by a pump having a rated capacity of 125 gallons per minute at a head of 35 pounds per square inch. Acid flows from the tank over a pan-type cooler, similar to the one installed at the burner-hydrator. This cooler is 30 inches wide and 12 feet long and the acid is cooled from 175 to 135 F.

The concentration of the acid produced is normally in the range of 55 to 60 percent  $\text{P}_2\text{O}_5$ . In order to produce superphosphoric acid (acid containing 76 percent  $\text{P}_2\text{O}_5$ , or 105 percent  $\text{H}_3\text{PO}_4$  equivalent) the amount of water added for hydration of the  $\text{P}_2\text{O}_5$  must be decreased; consequently, the amount of evaporative cooling is decreased and the temperatures in the hydrator and Venturi scrubber are increased. In order to avoid excessive temperatures and still maintain the normal phosphorus burning rate, acid collected in the Venturi scrubber assembly is sprayed into the hydrator for cooling.

Gas from the entrainment separator is exhausted to a 200-foot-high brick-lined stack. The gas is exhausted by a fan that operates at a speed of 1,750 revolutions per minute and has a rated capacity of 12,700 cubic feet per minute at a pressure of 33 inches of water and a temperature of 240 F. Weak phosphoric acid which collects in the exhaust duct and stack is drained to a small brick sump. From this sump the acid flows through a polyethylene pipe to the main collecting sump where it mixes with the other acid produced.

Figure 4 is a photograph of the vaporizer, burner, and hydrator, and Figure 5 is a photograph of the Venturi assembly.

Typical operating data for the No. 1 acid plant are given in Table 1.

#### Corrosion Problems

Much information has been reported in the literature on the corrosion rates of various metals when exposed to phosphoric acid. Some of the published articles<sup>1,4,5,10</sup> give results of tests carried out in the laboratory with chemically pure and commercial grades of phosphoric acid. Others<sup>11-16</sup> report experiences with various materials of construction in wet-process phosphoric acid plants. But the published articles on the serviceability of materials of construction for electric-furnace phosphoric acid plants are somewhat meager. One publication<sup>1</sup> presents corrosion data and discusses some of the corrosion problems encountered at the TVA acid plants; another<sup>17</sup> summarizes all the corrosion data obtained at TVA.

Subsequent to the earlier publications on corrosion of equipment in the TVA phosphoric acid plants, additional information has been obtained on the service life of the equipment used in these plants. Also, the phosphoric acid production units have undergone considerable modification and different corrosion problems have been encountered. Previously many of the corrosion problems were associated with the operation of the electrostatic precipitators used to collect the acid mist, but the installation of a Venturi scrubber to collect this mist at the No. 1 acid plant has changed the plant corrosion problems. Furthermore, considerable experience has now been obtained with a water-cooled graphite burner<sup>8</sup> for the combustion of phosphorus and collection of acid.

#### Vaporizer, Burner and Hydrator

At the vaporizer and duct between the vaporizer and burner the super-duty firebrick lining (a refractory produced by a dry process in which relatively dry clay is molded under high pressure before firing) satisfactorily resists attack by the hot, partially hydrolyzed  $\text{P}_2\text{O}_5$ . The super-duty firebrick linings have

TABLE 1—Typical Operating Data for Phosphoric Acid Production Unit

Phosphorus burning rate, lb. per hr.	2,650
Phosphoric acid production, tons $\text{P}_2\text{O}_5$ per day	71.7
Air flows, cfm at STP:	
Phosphorus atomizing air	150
Vaporizer combustion air	480
Burner combustion air	3,400
Temperatures, Degrees F:	
Vaporizer outlet	1,650
Burner Outlet	880
Venturi scrubber inlet	195
Stack gas	175
Pressure drop across Venturi, inches of water	25.2
Pressure drop across separator, inches of water	1.9
Acid concentration, percent $\text{P}_2\text{O}_5$ :	
Acid from burner-hydrator	64.7
Acid from Venturi scrubber	51.3
Acid from stack	14.5
Combined acid	59.3
Loss of $\text{P}_2\text{O}_5$ in stack gas, percent of phosphorus burned	0.2

TABLE 2—Corrosion Rates of Type 316 Stainless Steel Exposed to Phosphoric Acid at Different Temperatures

Acid Concentration, % $\text{P}_2\text{O}_5$	Material From Which Test Acids Were Made	Fluorine Content of Acid, %	Duration of Test, Days	Temperature of Acid, Degrees F	Corrosion Rates of Type 316 Stainless Steel Specimens, Mills per Year
50.1	Phosphorus	0.0004	6.0	200	9
50.1	Phosphorus	0.0004	3.9	225	45
50.1	Phosphorus	0.0004	6.0	250	127
50.2	Phosphorus Sludge	0.010	6.0	200	10
50.2	Phosphorus Sludge	0.010	3.9	225	20
50.2	Phosphorus Sludge	0.010	6.0	250	31



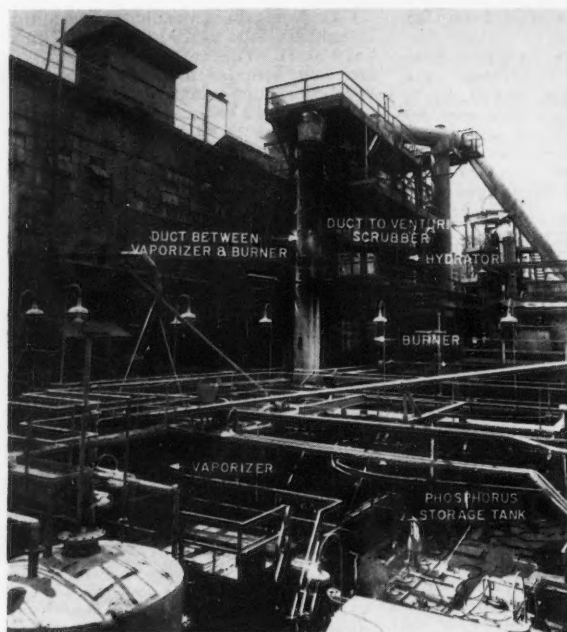


Figure 4—View of No. 1 phosphoric acid plant showing burner and hydrator.

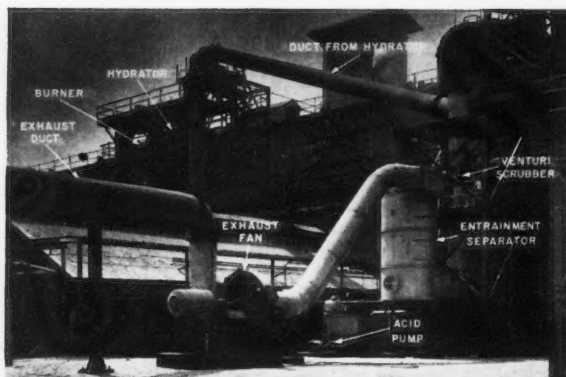


Figure 5—View of No. 1 phosphoric acid plant showing Venturi scrubber.

been in use more than three years without need for significant repairs. Stiff mud brick lining (a refractory in which the shaping is done by extrusion of a moist mixture before firing) used prior to the super-duty firebrick required patching after only a few months' operation.

Except for the bottom, the burner has required very little maintenance. After three years' operation the top had to be patched in some places and a few cracks in the walls had to be pointed up. Water-cooling the outside surface of the burner has effectively prevented oxidation of the graphite, and this, together with water sprays at the bottom of the burner, has lowered the gas temperature enough to prevent deterioration of the carbon blocks in the hydrator. The water cooling also removes heat from the gas and decreases the amount of evaporative cooling required; consequently, higher concentration acid can be produced for a given phosphorus burning rate.

Failures of the cement joints in the bottom of the burner and hydrator have caused considerable maintenance, and this

has resulted in appreciable acid leakage. The graphite and carbon blocks in the bottom of the burner and hydrator were originally cemented with a phenolic resin base cement, but after about a year's operation, acid leakage became a problem. A furan resin base cement is now used instead of the phenolic-base material, but the acidproof cement joints have to be pointed up at intervals of two to three months. Temperatures at the bottom of the burner and hydrator exceed the temperatures at which the resin-base cements are durable. Both high-temperature silicate and carbonaceous cements have been unsatisfactory; the former is washed out of the joints by water or weak phosphoric acid during startups, and the latter produces porous joints which permit the acid to leak through.

#### Venturi Scrubber

The Venturi scrubber is subjected to corrosion and erosion by the acid particles in the gas stream. When the unit was started, close checks were made

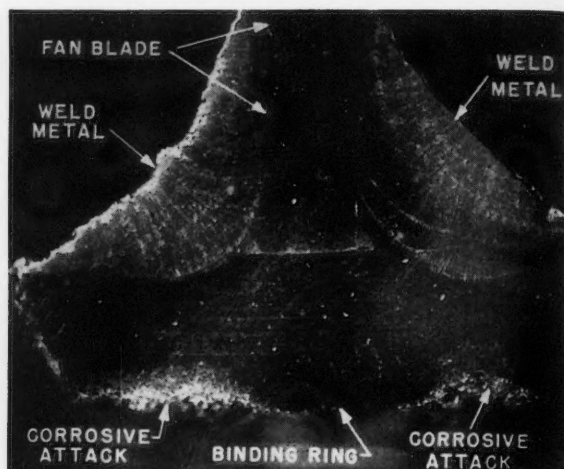


Figure 6—Photomicrograph showing corrosion of fan impeller. Original magnification, 8X; actual magnification after reduction for engraving purposes, 6X.

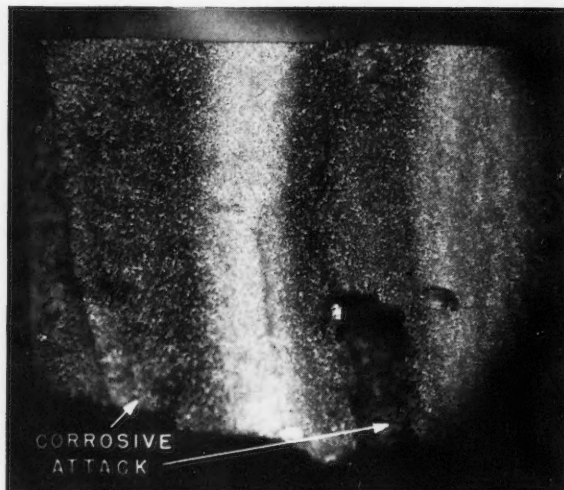


Figure 7—Photomicrograph of section of impeller binding ring. Original magnification, 5.5X; actual magnification after reduction for engraving purposes, 4.5X.

on the corrosion rates of the Type 316 stainless steel used in its fabrication. Laboratory corrosion tests were carried out to determine the effect of temperature on the corrosion rate of this steel exposed to phosphoric acid made in the plant when phosphorus (which contained 1.3 percent impurities) was burned and when sludge (which contained 14.3 percent impurities) was burned. Results of these tests are given in Table 2. The acid made from the phosphorus sludge had a greater fluorine content than acid made from the purer phosphorus; it was expected that the high fluorine content would increase the corrosion rates of the Type 316 stainless steel. However, a protective coating formed on the metal specimens exposed to the high-fluorine acid and the corrosion rates were less at 225 and 250 F than they were in the acid containing less fluorine. The laboratory data showed that without the protective coating, acid temperatures higher than about 225 F caused excessive corrosion of Type 316 stainless steel.

The corrosion rates of Type 316 stainless steel exposed in different parts of

**TABLE 3—Typical Corrosion Rate Data for Type 316 Stainless Steel Specimens Exposed in the Venturi Scrubber**

Duration of Test, Days	Material Burned	Temperature of Gas, Degrees F		Fluorine Content of Gas, Grams per Cubic Foot		Acid Concentration, Percent P <sub>2</sub> O <sub>5</sub>		Temperature of Acid, Degrees F		Fluorine Content of Acid, Percent		CORROSION RATES, MILS PER YEAR		
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Specimens Exposed in Cone Section of Venturi	Specimens Exposed in Acid Recirculating Tank	Specimens Exposed in Entrainment Separator
4.5	Phosphorus containing 1.3 percent impurities	196-215	206	0.001-0.003	0.001	49.4-51.5	50.4	182-195	189	0.0008-0.002	0.001	16.2	3.4	13.6
4.5	Sludge containing 14.3 percent impurities	185-222	204	0.002-0.033	0.009	46.0-49.8	48.0	174-200	186	0.005-0.026	0.012	34.6	2.7	14.4

the Venturi scrubber have been determined at various times. The steel was corroded at widely varying rates, depending on the temperatures and quality of phosphorus burned. Specimens of Type 316 stainless steel were exposed in the cone section of the scrubber at a point where the gas velocity was 120 feet per second. The corrosion rates at this point varied over the range of 9 to 217 mils per year. In the acid recirculating tank they varied from 2 to 12 mils per year and in the entrainment separator the rates varied from 2 to 37 mils per year. Typical corrosion rate data for the Venturi scrubber are given in Table 3.

Analyses of the gas at the Venturi scrubber showed that the concentration of fluorine was about nine times as great when sludge was burned as it was when phosphorus was burned. Most of the fluorine volatilized during combustion of the phosphorus and sludge was found in the exhaust gas, probably as hydrofluoric acid. The fluorine content of the acid also increased significantly when the sludge was burned. The corrosion rate of Type 316 stainless steel exposed in the cone section of the Venturi was about twice as great when sludge was burned as when phosphorus was burned. The higher corrosion rate with sludge was attributed to the higher concentration of fluorine in the gas and acid. In the recirculating tank and entrainment separator corrosion rates were not significantly affected by the quality of phosphorus burned.

It was necessary to replace the cone section of the Venturi scrubber after an operating time of about 1.35 years. On the basis of this service life, the overall corrosion rate was calculated to be 93 mils per year. Tests were made to determine the corrosion rates of various metals in order to find ones which would be more resistant than Type 316 stainless to the corrosive conditions in the cone section of the scrubber. Results of these tests, which were made at various times and under different conditions with regard to operating temperature and quality of phosphorus burned, are given in Table 4. Of the various metals tested, Nionel was somewhat more resistant than Type 316 stainless steel; 17-14 Cu-Mo, V2B and FA20 were slightly more resistant than Type 316 stainless steel. Type 201 stainless steel, which is an austenitic steel with higher manganese and lower nickel content than Type 316 stainless steel, corroded at a slightly greater rate than Type 316 stainless steel.

#### Gas Exhaust Equipment

The fan used to exhaust the gases to the plant stack failed after only two months' operation because the impeller (which was made of Type 316 stainless steel) was severely corroded. This im-

peller consisted of two rings with the fan blades butt-welded between these rings. The rings corroded on the side opposite the butt-welded blades.

Figure 6 is a photomicrograph of a part of the fan blade binding ring and shows where the corrosion occurred. The photomicrograph in Figure 7 is another view of the ring showing corrosive attack in the heat-affected areas. Closer examination showed that chromium carbide had precipitated at the grain boundaries, and it was concluded that corrosion was caused by chromium impoverishment of the austenite grain surfaces. Except in areas near the welds there was no evidence of corrosion of either the impeller or fan housing.

A fan impeller with blades secured by riveting instead of welding was installed, but the riveted impeller lasted only two to three months before replacement was necessary. The rivets came loose and caused excessive vibration. Finally, an extra-low-carbon (ELC) Type 316 stainless steel impeller fabricated by welding the fan blades was installed. Installation of the ELC Type 316 stainless steel impeller apparently has eliminated the corrosion problem, although mechanical failures of the fan have occurred.

The gases at the exhaust fan contain 150-250 parts per million of fluorine (assumed to be present as hydrofluoric acid) and 2,700-7,400 parts per million of P<sub>2</sub>O<sub>5</sub> present as entrained phosphoric acid particles. The gas temperature is in the range of 160 to 180 F. A wooden duct formerly was used to conduct the exhaust gases to the plant stack, but this duct was not very satisfactory because the service life was only about two years, and acid leakage occurred, even though the duct was new.

Tests were made to determine which metals might be used in place of the wood for fabrication of the duct. The metals tested were Types 430, 302, 304, and 316 stainless steels, Hastelloy B, Everdur 1010, Monel, Monel S, Monel K, deoxidized copper, red brass, Carpenter 20, nickel, Inconel, Ni-Resist, mild steel, and cast iron. Of these metal specimens, only Type 316 stainless steel, Carpenter 20, and Hastelloy B had corrosion rates less than 50 mils penetration per year. Type 316 stainless steel specimens were corroded at rates of 1 to 16 mils per year. Welded specimens of Type 316 stainless steel were corroded at about the same rate as unwelded specimens. On the basis of the test results and the relative costs of the more resistant metals, ducts were fabricated from Type 316 stainless steel. The stainless steel ducts have been in use about 5½ years and patching as a result of corrosion has been necessary only during the past few months (except for repair of the welds in which Type 347 stainless steel welding rods were inad-

**TABLE 4—Relative Corrosion Resistance of Various Metals Exposed in the Cone Section of the Venturi Scrubber**

Metal	Manufacturer	Relative Corrosion Rate as Compared With Type 316 Stainless Steel*
Nionel	International Nickel Company.....	0.4
17-14 Cu-Mo	American Rolling Mill Company.....	0.7
V2B	Cooper Alloy Foundry Company.....	0.8
FA20	Cooper Alloy Foundry Company.....	0.8
Durimet 20	Duriron Company.....	1.1
Type 201 Stainless Steel	.....	1.1
Chlorimet 3	Duriron Company.....	2.6
Hastelloy B	Haynes Stellite Company	2.7
Monel	International Nickel Company.....	8.6
Type 430 Stainless Steel	.....	11.8
17-4PH	American Rolling Mill Company.....	11.8

\* Corrosion rate of the test metal divided by the corrosion rate of Type 316 stainless steel obtained during the same test.

vertently used instead of Type 316 stainless steel rods).

The phosphoric acid is stored in either rubber-lined steel tanks or in brick-lined wooden tanks having a lead membrane. The rubber-lined tanks require less maintenance than the brick-lined tanks; however, the acid temperature must be 150 F or lower to prevent damaging the rubber. Much higher acid temperature can be tolerated when the acid is stored in brick-lined tanks.

Tests of a small storage tank made of mild steel and lined with acidproof brick with a ½-inch thick synthetic rubber membrane indicated that this type of storage tank construction was satisfactory for phosphoric acid. The acid strength was about 58 percent P<sub>2</sub>O<sub>5</sub> and the temperature was 200 F. Preliminary laboratory test results of various plastic and rubber base materials exposed to superphosphoric acid have indicated that the attack by this acid is no greater than the attack by acid of normal concentration.<sup>2</sup>

The maintenance of adequate painted surfaces is another corrosion problem encountered during the production of phosphoric acid. Painted surfaces must be impervious and resistant to attack by the plant fumes in order to provide adequate protection to steel surfaces. Paints may be purchased which contain plastic materials highly resistant to corrosive conditions.

Numerous paints were tested by exposing painted test panels in the plant area. The test panels used were a development of Kenneth Tator Associates<sup>18</sup> and were designed to measure the durability of the paints on several types of metal surfaces, such as, planes, edges, welds, crevices, projections, etc. Paints tested included the following base types: oil, rubber, synthetic rubber, chlorinated rubber, vinyl, epoxy, furan, neoprene, phenolic, and bitumen. Results of these tests indicated that no particular base type of paint was superior to the others for painting steel at the phosphoric acid production unit.

Adhesion of the paint was a more important factor than the chemical resistance of the paint film. Consequently, oil base paints having good adhesive properties when applied to steel surfaces were as satisfactory as paints containing the more chemically resistant plastic or rubber materials. Undercutting of the paint film at places where the film had been deliberately damaged on the test specimens was usually the cause of the first paint failures. Paints of different vendors having the same base type varied widely in durability. This indicated that methods of formulating had a significant effect on the durabilities.

#### Conclusions

The highly corrosive conditions encountered during the production of phosphoric acid necessitates careful choice of the materials used in construction of the equipment in order to keep corrosion problems to a minimum. During the production of phosphoric acid by the electric-furnace process, corrosion problems are accentuated by the high temperatures involved, but many of these problems can be avoided by proper design and by proper choice of the materials of construction for the manufacturing facilities. The equipment design should be based on the limitations of the materials of construction used and on reviews of corrosion problems encountered previously during the production of phosphoric acid.

At the TVA plant the problem of

corrosion during the combustion of phosphorus has been minimized by using water-cooled graphite blocks as materials of construction. The graphite blocks have proved to be a satisfactory construction material except at the bottom of the burner where high temperatures deteriorate the resin base cements and cause considerable maintenance. Because of this problem, future graphite chambers for combustion of phosphorus should provide adequate cooling of the bottom in order to protect the resin cement joints. Such cooling might be obtained by recirculation of cooled acid to the combustion chamber. Other plants apparently have solved successfully the problem of corrosion during the combustion of phosphorus and hydration of the  $P_2O_5$  by the use of stainless steel vessels protected by water jacket cooling of the steel.<sup>9</sup> Both approaches to the problem involve cooling the materials of construction to temperatures below which significant oxidation or corrosion occurs.

Type 316 stainless steel generally resists corrosion in phosphoric acid plants when the temperatures are no greater than about 225 F and when the steel is not subjected to highly erosive or abrasive conditions encountered at high gas or liquid velocities. Some more costly steels have greater corrosion resistance than Type 316 stainless steel and the more costly steel may be more economical for the construction of small equipment where unusually severe corrosive conditions exist.

Considerable savings may be realized at both wet-process and electric-furnace process phosphoric acid plants by further reduction of maintenance cost incurred as a result of corrosion of the materials of construction. At the TVA plant repair and maintenance costs for the production of phosphoric acid from elemental phosphorus amount to about \$2.00 per ton of  $P_2O_5$  in the acid produced, or about 42 percent of the manufacturing costs. For wet-process phosphoric acid plants, it is estimated that the repair and maintenance cost for a

large plant (30,400 tons of  $P_2O_5$  per year) is \$2.56 per ton of  $P_2O_5$  in the acid produced, or 16 percent of the manufacturing cost.<sup>19</sup> The use of new, more resistant materials for construction of equipment for phosphoric acid production, and the application of design and operating techniques for minimizing corrosive conditions offer possibilities for further reduction of the corrosion problems and decreasing repair and maintenance costs.

#### Acknowledgments

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Any discussions of this article not published above will appear in the December, 1958 issue



# Weather Versus Cathodic Protection Of Underground Pipe Lines\*

By F. E. COSTANZO

## Introduction

CORROSION ENGINEERS have long been curious about the influence of weather on the effectiveness of cathodic protection of underground structures. Fragmentary data obtained from surveys made under different weather conditions do little to clarify this matter. Rectifier current data at best were no better than monthly readings, and the weather data for the corresponding periods of time were obtained from stations located perhaps 50 or more miles from the installation.

The Corrosion Department of The Manufacturers Light and Heat Company decided in 1950 to initiate an investigation which would compare daily weather data with daily rectifier readings. The data presented here are the result of that investigation to date. A number of interesting conclusions and deductions can be made from the data, only the most significant of which will be discussed.

## Test Procedure

It was necessary at the outset to locate a bare pipeline of recent construction, adjacent, or at least not far removed from, a United States Weather Bureau station. As luck would have it The Manufacturers Light and Heat Company in 1948 had installed a 20 inch bare pipeline that passed through the compressor station yard of Manufacturers' Waynesburg Compressor Station. This pipeline had a telephone pole line extending along the right of way approximately 10 to 20 feet from the pipeline, and the station personnel at the Waynesburg Compressor Station operated the United States Weather Bureau station for Greene County, Pennsylvania. Thus the first 19,500 feet of this pipeline was selected as the corrosion controlled pipeline for the investigation.

The 20 inch bare pipe had been laid in a 54 inch deep trench, with an average of 30 inches of cover to the top of the pipe. A 20-volt 40-ampere General Electric rectifier was used to supply cathodic current. Figure 1 shows the United States weather station located approximately 100 feet from the rectifier at the Waynesburg Compressor Station.

Figure 2 shows the rectifier and the pole line extending away from the station. A distributed ground bed was installed with anodes located at the base of each pole; the pole spacing varied from 150 to 250 feet. A 3/0 bare aluminum cable was used as a gathering wire, with No. 10 copper wire for the drop leads to the anodes. One hundred and ten magnesium anodes were used on the

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original installation, with one magnesium anode at the base of each pole.

Magnesium anodes were used as the original ground bed in order to determine their efficiency. That study continues independently of the weather investigation. Several of the magnesium anodes were completely consumed after 30 months of operation, and most of the remainder were replaced after four years of operation. The replacement anodes are aluminum, graphite, or Duriron.

Figure 3 is a strip map of a typical section of the line showing the ground bed installations and the soil resistivity profile. Normal variations in resistivity were from a low of 3,850 ohms per cubic centimeter to 34,000 ohms per cubic centimeter. However, resistivity of 125,000 ohms per cubic centimeter was indicated at Station 25. Single anode output varied from 28 milliamperes in 125,000 ohm soil to 380 milliamperes in 3,850 ohm soil. In August of 1950 the initial output of the rectifier to provide adequate cathodic protection was 24 amperes at 18 volts for the 19,500 feet of 20 inch pipe.

The basic procedure for determining minimum current requirement is the method which indicates a change in the "on and off" pipe to  $\text{CuSO}_4$  potential. The McCollum earth current meter<sup>1</sup> was used to spot check areas where very slight changes between "on and off" were noted, and adjustments were made to increase the output of the rectifier where the earth current readings were positive. In the valuation, the importance of knowing the minimum cathodic protection current required is obvious.

Four major pipelines cross this section of the test line, and equalization

## Abstract

A comparison is made between weather data and cathodic protection survey data of a four-mile section of 20-inch bare pipe line in southwestern Pennsylvania over a period of five years. The relationship between rectifier current output and rainfall, soil temperature and mean daily temperatures are considered.

It was found that temperature has little or no effect on cathodic protection required. Precipitation of more than one-half inch, when it occurs in the form of water, makes a definite change in the cathodic protection current requirement. The effects of precipitation are transient, current requirement returning to normal as soon as the rain stops. Precipitation in the form of snow has much less effect upon cathodic protection than does its water equivalent.

8.9.3

bonds have been established with the agreement of the companies concerned. The current requirement for these bonds totaled 1.632 amperes.

Since August of 1950, there have been daily readings taken at 7:30 am showing the weather information, including temperature and rainfall, and at the same time showing the reading on the ammeter at the rectifier. Corrosion surveys of the pipeline have been made annually; Figure 4 shows a typical section of pipeline with the corresponding  $\text{CuSO}_4$  potential taken every 25 feet along the line.

This report covers data collected for the period from January 1951 through December 1956.

## Comparative Results for 1951

In order to picture any possible correlation between atmospheric tempera-



Figure 1—Weather station at The Manufacturers Light and Heat Company's Waynesburg Compressor Station, Waynesburg, Pennsylvania.

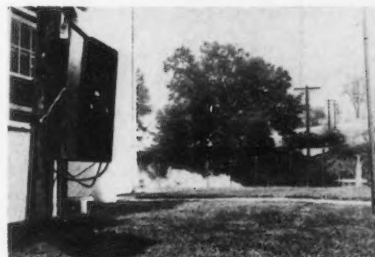


Figure 2—Cathodic protection rectifier installation.

\* Submitted for publication December 6, 1957. A paper presented at a meeting of the Northeast Region, National Association of Corrosion Engineers, Pittsburgh, Pa., November 13, 1957.

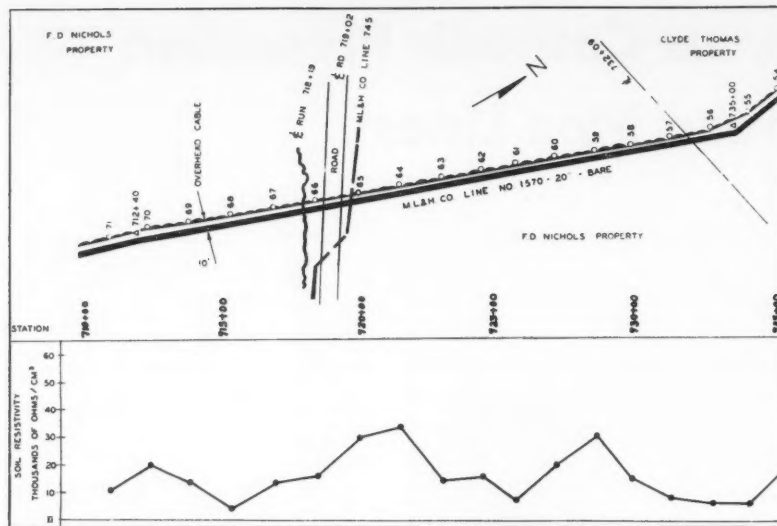


Figure 3—Distributive ground bed installation and soil resistivity survey.

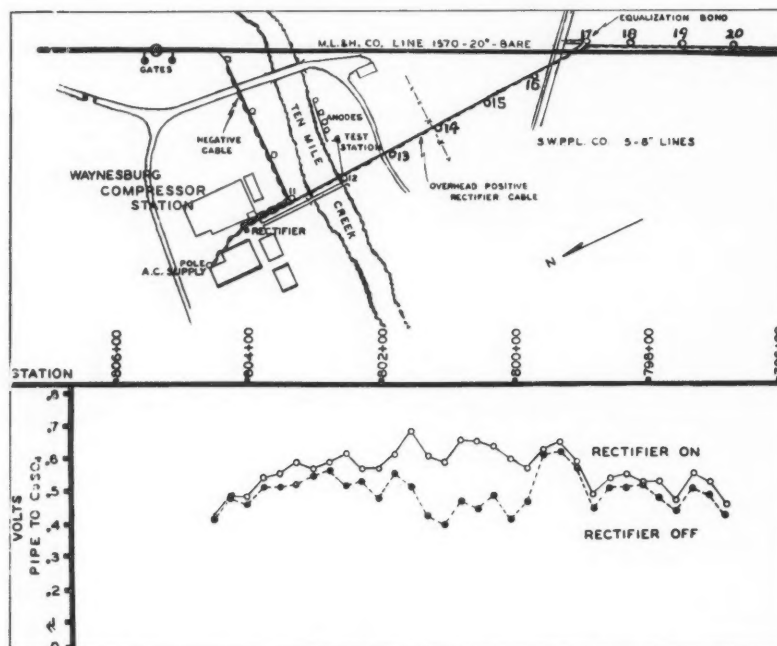


Figure 4—Waynesburg compressor station cathodic protection layout and pipe to copper sulfate survey.

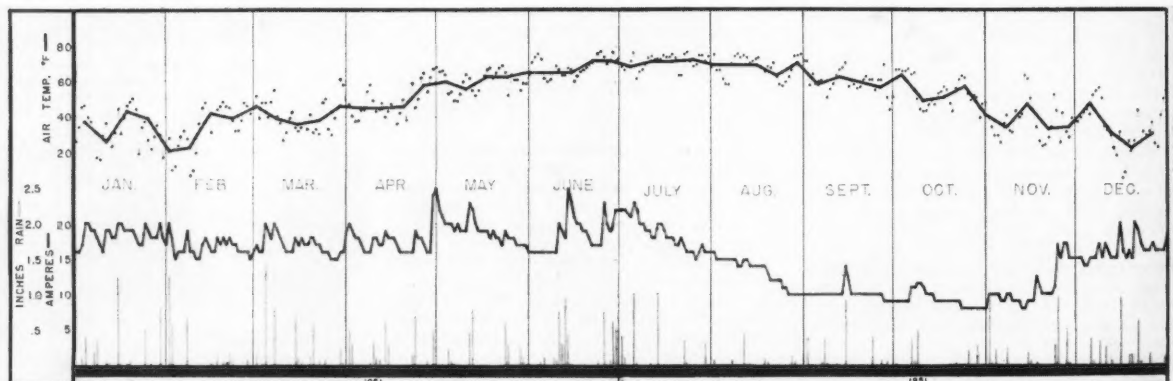


Figure 5—Daily readings (1951) of atmospheric temperature, rainfall, and cathodic protection.

ture, rainfall, and current requirements as shown by the ammeter reading on the rectifier, three items have been plotted on successive curves by calendar years. Figure 5 gives the data for the calendar year 1951. At the top of the chart is a plot of the daily temperatures taken at 7:30 am each day. Superimposed on this data is a 7-day average. The middle curve on the chart is a plot of the output of the rectifier in amperes as read at 7:30 each morning. The bottom curve is actually a bar-graph showing, to scale, the number of inches of rainfall in the preceding 24 hours.

As is to be expected, the atmospheric temperature shows itself to be an annual one-cycle curve with waves representing colder or warmer periods. The plot of current output from the rectifier seems to have no regular cycle, except for the fact that in this particular year there was a low output during the months of September, October, and the first half or two-thirds of November.

There is no sign of any correlation between atmospheric temperature and cathodic protection current. For example between the first of September and the end of November there was a general decline in the atmospheric temperature. However, the current output maintained a general level, practically uniform, except that during the latter part of November the current output increased slightly while at the same time the temperature was decreasing.

Comparison of the current output and the water or rainfall curve is a totally different matter. Here it becomes obvious that rainfall does affect the current curves. One of the more startling variations occurs about the middle of September when after several days of little or no rainfall, there was approximately 0.8 of an inch of rainfall and the current for that day had a sharp increase.

There appears to be, in the data of this curve, some breaking point at which rainfall has an effect on current consumption. Consider, for example, the first few days and the last few days of September. On both of those occasions there was approximately 0.4 of an inch of rainfall but no increase in cathodic current. Again note the middle of September, where there was one day with more than a half inch of rainfall and a corresponding sharp increase in current requirement. From the data on this curve one would be tempted to say that the current requirement would increase when the rainfall is more than 0.5 of an inch in a day.

It should be borne in mind that as plotted on this bar-graph all rainfall is

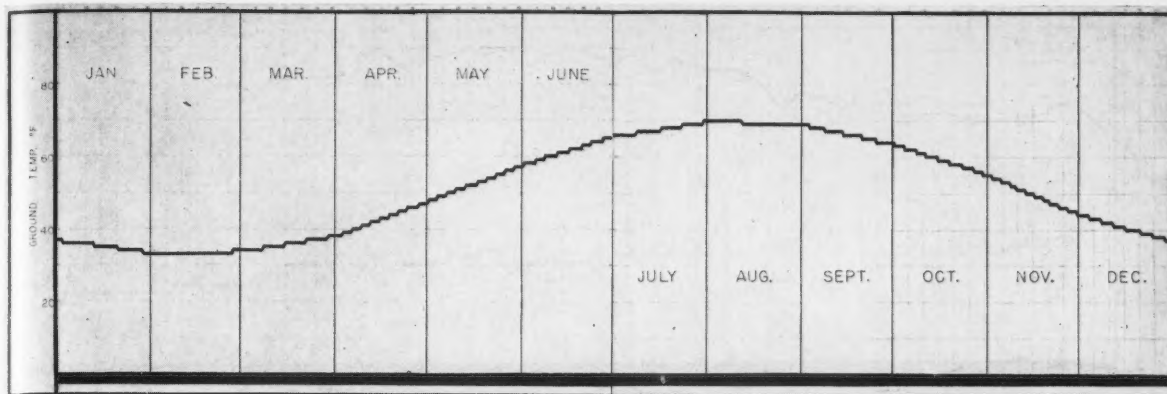


Figure 6—Daily ground temperatures.

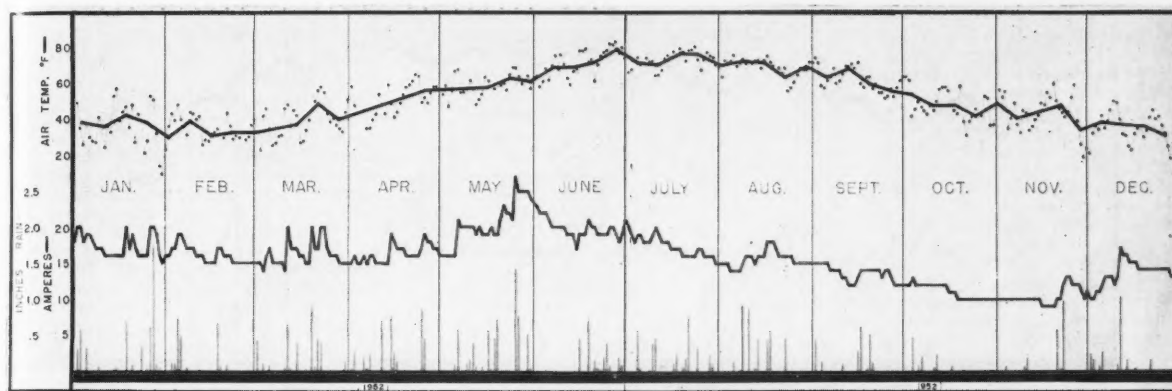


Figure 7—Daily readings (1952) of atmospheric temperature, rainfall and cathodic protection.

shown in equivalent inches. Snowfall, for example would be reported in inches of water. On the 15th of January 1951, there was approximately 20 inches of snowfall equivalent to 1.28 inches of water when melted. The snow did not immediately melt and there was no sharp increase in current requirement. It would appear that snowfall does not cause an immediate change in current requirement, but rather furnishes the water over a greater period of time to maintain higher current requirement than when there is no snowfall or rainfall.

For the year 1951, the period of maximum current requirement occurred in June, with an almost equal current requirement at the end of April and the first of May. The minimum corrosion period was during the months of September, October, and the first part of November with the tendency to corrode, as indicated by current requirements, increasing during the latter part of November and maintaining a relatively uniform level from then until the latter part of April. Data such as that shown by the experience in 1951 has been pointed to by many corrosion engineers as indicative of the existence of a two-cycle annual curve for corrosion rate. Successive charts for the years following 1951 will show that this is not a general fact, but rather, may be a fact for a particular year.

#### Daily Ground Temperature

It was noted that while current requirement did not vary with atmospheric

temperature, it was possible that it might vary with the ground temperature. To refute this contention, data collected from the Bureau of Mines<sup>2</sup> showing ground temperatures at various depths for various geographical areas is plotted in Figure 6. The particular data plotted are for a depth of 30 inches in the Pennsylvania-Appalachian area. Here, again, is a simple one-cycle curve which actually follows rather well the average atmospheric curve. Comparing this curve with that for current requirements for the year 1951 again discloses no more relationship between current and ground temperature than there was between current requirement and atmospheric temperature.

#### Comparative Results for 1952

Figure 7 is a plot of the data for the calendar year 1952. Once again, the temperature data, either daily or by 7-day means, follows the single-cycle atmospheric curve.

In inspecting the bar-graph and the current requirement, it is noted that when there is a lot of rainfall the current requirement goes up; when there is no rainfall, the current requirement goes down, regardless of what the atmospheric or ground temperature may have been. The periods of maximum corrosion as indicated by current requirements are in the months of May and June, as they were for 1951, and the months of October and November indicate the minimum corrosion period. The heavy rainfall increased toward the end of the month of

May 1952, and the current requirement built up steadily as the rainfall continued. Rainfall gradually fell off during the month of September. There was little or no rainfall except during the first part of October, and practically none until the last third of November, and then during that period the tendency to corrode as indicated by the current requirements fell steadily, then held at a constant.

Now for a look at the effect of the magnitude of the daily rainfall. Consider the month of January, for example, when there was one day with more than an inch and a half of rainfall followed by a number of days with little or no precipitation. Immediately, the current requirement jumped from slightly over 15 to approximately 20 amps, and immediately fell back to 15 when the rainfall did not continue. There were small amounts of rainfall in the first week of February, and then a day with approximately one-half inch, after which time the current requirement immediately increased.

In comparing the rainfall curve with the shape of the curve above it, it is noted that 0.5 of an inch or more of rainfall does produce peaks. The prime exception to it for this year seems to be during the latter part of July when 0.5 of an inch of rainfall had very little effect on corrosion requirements. This could well have been due to the fact for the previous seven weeks there had been a less than normal amount of rainfall, with the result that the ground had



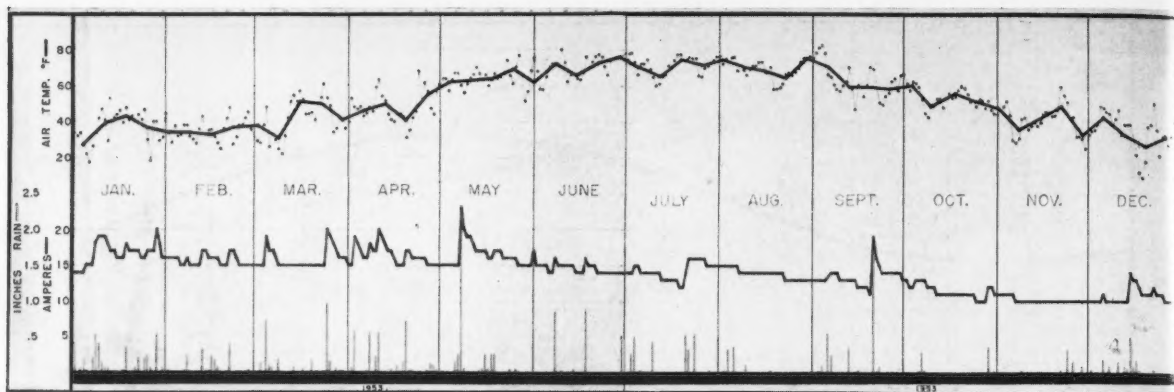


Figure 8—Daily readings (1953) of atmospheric temperature, rainfall and cathodic protection.

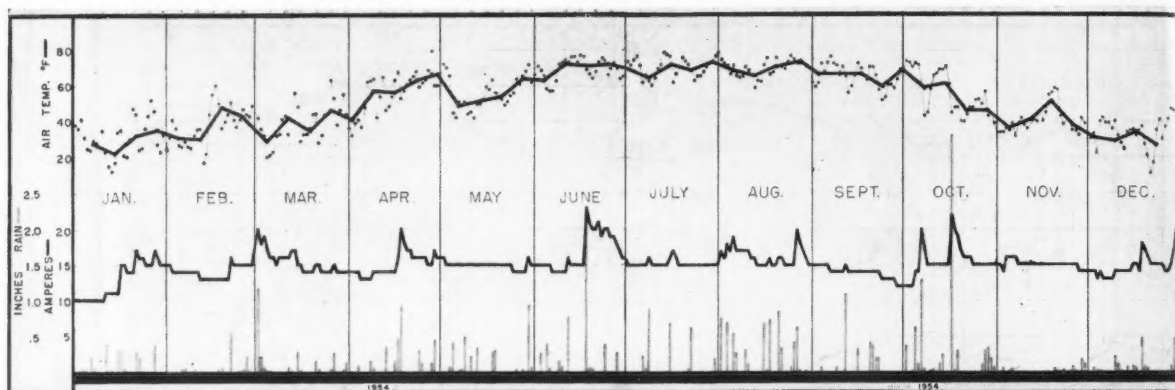


Figure 9—Daily readings (1954) of atmospheric temperature, rainfall and cathodic protection.

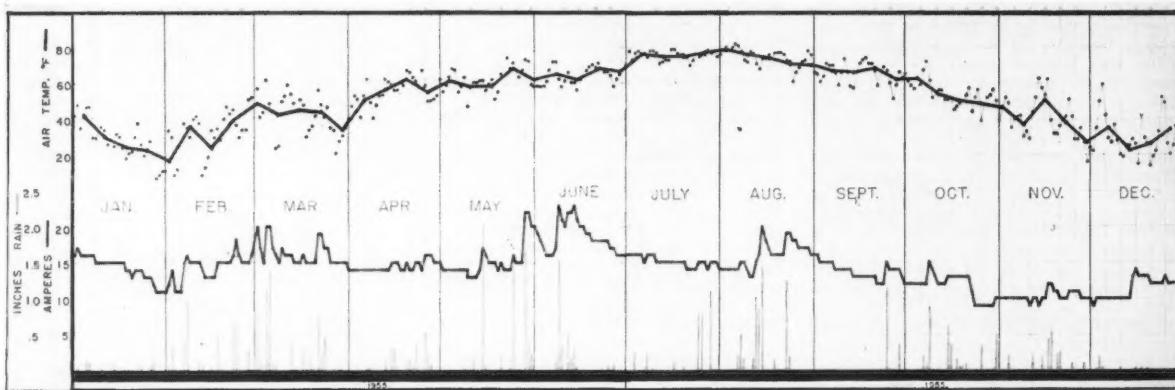


Figure 10—Daily readings (1955) of atmospheric temperature, rainfall and cathodic protection.

become particularly dry and resistance particularly high.

#### Comparative Results for 1953

The data for the year 1953 are plotted in Figure 8. Because rainfall was uniformly off for the entire year, there is no continued plateau of high corrosion tendency. Once again the absolute high for the year occurs in the month of May, and is coincidental with the occurrence of more than 2¼ inches of rainfall in one day. Considering just the data of this curve, there is a single

cycle of corrosion tendency at a higher level during the winter, spring, and early summer months and at a lower level during the late summer and early fall months. The almost continuous level of current requirements for the entire year would in itself be condemnation of any conclusion that either atmospheric temperature or ground temperature had anything whatever to do, from a fundamental nature, with current requirements. The waves superimposed on the annual curve of current requirements coincide with precipitation. Consider, for example, the

first rainfall in September that exceeded 0.5 of an inch. The current requirement curve had an increase, followed, because there was no further rainfall, by an immediate decrease. When in the latter part of September, there was a rainfall again of approximately 2 inches, there was an immediate increase in current requirement. For this particular installation, at least, it becomes more and more apparent that 0.5 of an inch of rainfall is the critical amount of rainfall to produce an increase in current requirements.

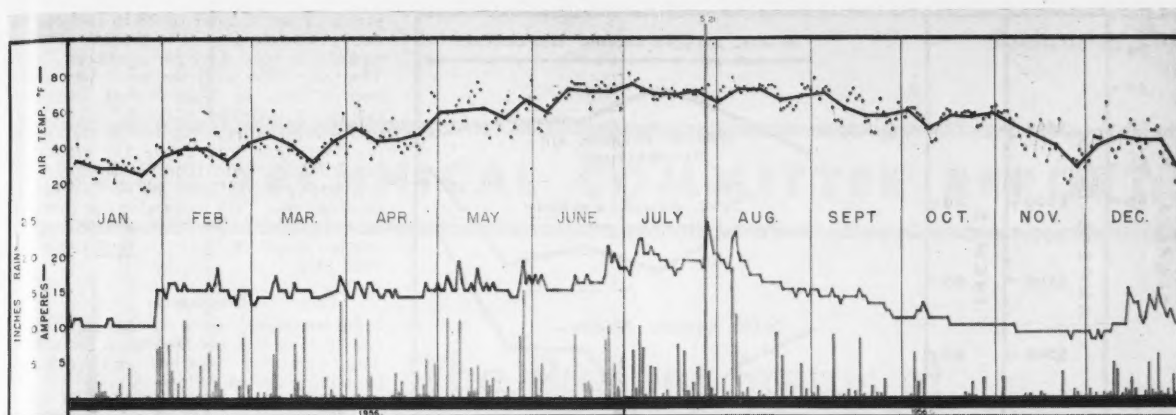


Figure 11—Daily readings (1956) of atmospheric temperature, rainfall and cathodic protection.

#### Comparative Results for 1954

Data for the year 1954 are plotted in Figure 9. There is little or no indication of even the annual cycle of current requirements on this curve, and it may be that this is a reflection of the extremely dry period during the year 1953 and drier than normal period during the year 1952. The absolute high for the year still occurs in the month of June, and is coincidental with a day when the rainfall was more than 2 inches. There was no general low period in October or November, even though the month of November had practically no rainfall.

The highest rainfall or greatest rainfall for the year occurred approximately in the middle of October, and there is a corresponding increase in current requirements for that day and the day following. The amount of rainfall on this particular day in October was decidedly more than the normal amount for any one day for the year, much less for the month of October. This leads to speculation concerning whether or not an excessive amount of rainfall has an excessive effect on current requirements. The comparison of current requirements on this day with a day about the middle of June when the amount of rainfall was slightly over 2 inches, with almost equal current requirements on both occasions, indicates that rainfall in excess of 2 inches does not have a proportionate effect on current requirements.

There are data on a succeeding year to help substantiate this conclusion setting the top limit for the effect of rainfall. It may be possible to set a current increase as the maximum that is likely to occur, regardless of the magnitude of the rainfall, if the rainfall exceeds 1.5 inches. For example, comparison of the data for October 16 and June 17 of 1954 indicates an 8 ampere increase in both cases, even though the precipitation was 3.3 inches in October and 2.55 inches in June. In checking back over this curve, and over other curves for precipitations between 0.5 inch and 1.5 inches, it is found that the major effect on cathodic current requirements when rainfall is in excess of 1.5 inches is the number of days it takes for the current to return to the normal or to the figure that it was before the rainfall. There is one additional factor to be added here, and that is that the effect of rainfall seems to be more lasting in the months of May and June than it is in the months of September and October. One surmise

with respect to this is that it is a function of the plant life on the surface of the ground.

#### Comparative Results for 1955

Figure 10 is a plot of the data for the calendar year 1955. The data for the months of January and February and the first two-thirds of March represent the kind of isolated data that is sometimes quoted to indicate a relationship between atmospheric temperature and the current requirements for cathodic protection. Starting with the first of January and continuing to the end of the month, the atmospheric temperature is gradually falling and so is the requirement for current. For a short period of time in the early part of February, the temperature increases and immediately the current requirement increases; the temperature decreases during the middle of the month, and the current requirement decreases in the middle of the month. Toward the end of the month the atmospheric temperature warms and the current requirement goes up. However, the correlation fails beyond the month of March. The temperature continues to rise through the month of April and the current requirement has gone back down to the low point, or the same point, that it was during the first half of January.

Again, as in other years, a maximum current requirement occurred during the latter part of May and the first part of June. And again, the minimum current requirement was reached during the months of October and November. Once again, take particular note of the humps or waves in the current requirement curve directly in line with the corresponding bar-graphs indicating rainfall of more than 0.5 inch. And particularly note, also, that when the rainfall was more than 1.5 inches there was no substantial change in the current requirements beyond that required for rainfall of just under 1.5 inches.

The latter half of May illustrates another point that has been noted from time to time in comparison of rainfall and current requirements through these years, and that is that a recurrence of rainfall of more than 0.5 inch but not more than 1½ inches produces a greater proportionate change in current requirement when the recurrence is within a very few days. In June on this curve, a rainfall of approximately 1½ inches produced a peak corrosion condition, and successive days of rainfall of 0.5 inch or

slightly less produced a sustaining effect on that corrosion condition. However with the absence of rainfall after the middle of June, the curve immediately declines to about the level of the preceding months of February, March, and April. In fact, successive rainfalls of more than 0.5 inch separated by one or two days each time, produced only localized waves on the general current requirement curve. In the latter part of August, however, successive days of rain of more than 1 inch produced pronounced change in the current requirement curve, and one additional day of rainfall of more than ½ inch was sufficient to sustain that curve over the latter part of August and the first half of September.

#### Comparative Results of 1956

During 1956 (see Figure 11) there was a total of 57.22 inches of precipitation, more than twice as much as during the dry year of 1953, and 30 percent more than the next highest year of 1951. This year also was notable for one other bit of data (i.e., on July 27 there was 5.21 inches of rainfall in a 24-hour period, by far the most precipitation on any single day for the period of the study to date).

For this year, the period of maximum current requirements were registered during the latter part of June, the month of July, and the early part of August. The minimum requirement, again, was noted during the months of October and November, except that January of this year was at approximately the same level as October and November—about 10 amperes.

One noteworthy fact about the January data was that what precipitation did occur, occurred as snowfall, except for rainfall occurring the last three days of the month. It is interesting to note that the current requirement remained at practically a constant level, except for the last three days when it immediately increased to approximately 15 amperes.

It is obvious from a comparison of current requirements, rainfall, and ambient temperature, on this curve and on those previously presented, that when the ambient temperature is below 32 F, indicating that what precipitation occurs occurred as snowfall, the current requirements are slow to build. This undoubtedly is due to at least two factors: (1) the slow dissipation of water which occurs by reason of the melting of the snow over a period of time, and (2) the

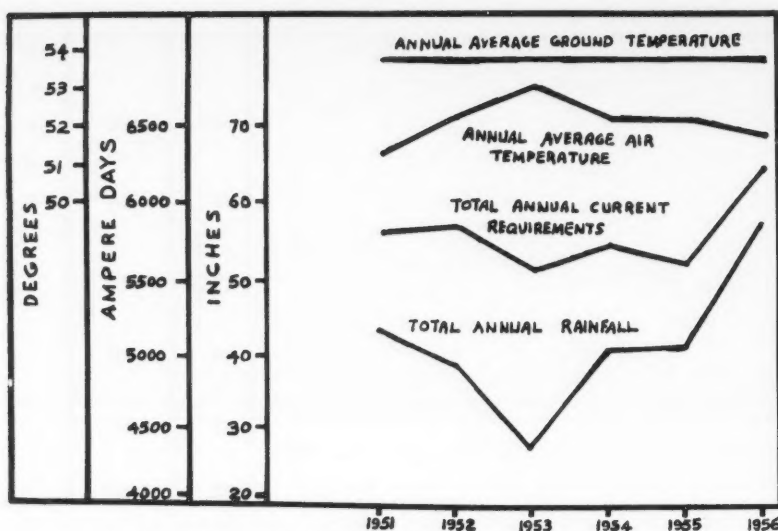


Figure 12—Annual averages of weather and cathodic protection current.

fact that much of the precipitation falling in the form of snow never reaches the ground, but instead is evaporated into the atmosphere.

With respect to July 27, when there was more than 5.2 inches of rainfall, it will be noted that the current requirement barely exceeded that for the day in the first week of August when the rainfall was approximately 1.7 inches, again illustrating the fact that beyond 1½ inches of rainfall the major portion of the water runs off the surface of the ground, and has little or no effect upon the conductivity of the soil at the depth of the pipeline. This certainly was true of this date of July 27, for with the station located in a valley, there was more than 20 inches of water on the operating floor at the Waynesburg Station the evening of the day with this 5.2 inches of rainfall.

#### Discussion

An attempt was made to determine the reason for the ordinarily greater corrosion tendency occurring in the months of May, June, or July, and the lesser corrosion tendency ordinarily occurring in the months of October and November. There is an additional postulate regarding this swing between spring, summer, and fall other than that possible by temperature of atmosphere alone. It is that the increase in corrosion tendency during the summer months and the decrease in the fall or winter months may be produced, in part, by bacterial corrosion.<sup>3</sup> Previous investigators<sup>4,5</sup> of bacterial corrosion have reported seasonal variations in the bacteria

populations, and that the anaerobic bacteria, including the sulfate reducing bacteria, accelerate the tendency to corrode. Some bacteria can live only when supplied with dissolved oxygen, others grow only in the absence of oxygen. The heterotrophic bacteria require organic matter as a source of energy. The autotrophic utilize inorganic substances as energy sources. All of them are affected by ground temperature in that they grow more rapidly under warm ground conditions or fail to grow at all under cold conditions, and that they require adequate moisture for their propagation. Regardless of the ground temperature, the bacteria do not grow in the absence of adequate moisture. For this reason even the effects of bacterial corrosion are materially influenced by rainfall or precipitation. In order to determine the overriding influence of bacterial corrosion, an additional investigation has been instigated utilizing the company's recent developments of the Redox Probe.<sup>6</sup>

#### Summary

Figure 12 is a summary curve of the data for the years 1951 through 1956, showing the annual average ground temperature, the annual average air temperature, the total annual current requirement, and the total annual rainfall. The configuration of the total annual current requirements with the total annual rainfall, and the complete lack of configuration with either the annual average air temperature or the annual average ground temperature is obvious. The year 1953 with the least amount of

precipitation, a total of 28.16 inches for the year, required the least cathodic current, a total of 5,143 amperes days. The year 1956 with the most precipitation, a total of 57.21 inches, required the most cathodic current, a total of 6,451 amperes days. In substantiation of the contention that above 1½ inches of rainfall at a time there is little or no increase in the cathodic current required, consider that 1956 had twice the precipitation of 1953 but required only 25.4 percent more cathodic current than the year 1953.

#### Conclusion

In summary, some of the significant conclusions that can be drawn from this data regarding weather and cathodic protection are as follows:

1. Atmospheric temperature and ground temperature are relatively smooth single-cycle curves, whereas the cathodic current curve appears as an irregular curve extending above and below a general plateau. It may be influenced by a variable, bacteria. Temperature has little or no effect on cathodic protection required.

2. Precipitation of over ½ inch, when it occurs in the form of water, makes a definite change in the cathodic protection current requirement.

3. Precipitation in excess of 1½ or 2 inches of rainfall has little more effect upon cathodic current requirements than precipitation between ½ inch and 1½ inches to 2 inches of rainfall, due to the effect of "run-off" from the surface.

4. The effects of precipitation are transient. As soon as the rainfall stops, cathodic protection current begins to return to normal. The number of days required to return to normal may be affected by the magnitude of the rainfall.

5. Precipitation in the form of snow has much less effect upon cathodic protection than the water equivalent of that precipitation.

6. Corrosion engineers desiring to determine the adequacy of cathodic protection for an underground structure should conduct those tests following ½ inch or more of rainfall, and that preferably during the months from May through August.

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Any discussions of this article not published above will appear in the December, 1958 issue



# NACE TECHNICAL COMMITTEE REPORT

## The Present Status of The Oil Ash Corrosion Problem\*

Progress Report of NACE Task Group  
T-5B-3 On Oil Ash Corrosion\*

### Introduction

**T**HE PURPOSE of this paper is to describe the work of NACE Task Group T-5B-3 and to record the present status of the oil ash corrosion problem. As noted below several of the members of the task group contributed case histories from their records. Therefore, this report is a co-operative effort.

The objective of the high temperature committee T-5B is to study the behavior of materials above 400 C. Task Group T-5B-3 more specifically studies the oil ash corrosion problem.

It is a matter of general knowledge that in the burning of residual oil the ash forming constituents are responsible for the major corrosion difficulties. These ash forming constituents are compounds containing sodium, sulfur, and vanadium as well as other elements. Without doubt there are problems in the ordinary combustion system other than those connected with the oil ash, but the committee has focused its attention on this aspect.

The task group has set several rather definite goals.

1. To keep informed on what is going on in the field. For example, the Gas Turbine Panel of the ASME-ASTM Joint Committee has an effort paralleling that of the task group.
2. To correlate and analyze in a critical manner the data that have been reported on this subject.
3. From this analysis of the data, to define the problem. The oil-ash corrosion problem is rather complex. The actual corrosion reactions that occur depend not only on the chemical species present but also on the conditions of operation.
4. To make available to those working in the field the literature pertinent to the subject. Exactly how this will

Unusually severe corrosion has been reported in systems burning residual fuel. This has been attributed to the high vanadium content of the oil, the sulfur content, or the presence of sodium chloride. Five case histories involving failures in the field are reviewed with the objective of pointing out the characteristics of the problem. The proposed solutions include (a) the use of inhibitors, (b) changing the alloy composition, (c) lowering operating temperature, and (d) altering composition of the oil. These alternatives are discussed. 8.4.1

be done has not yet been decided. A bibliography or collection of abstracts is a possibility.

At the first meeting of the task group in San Antonio in October of 1956 it was decided that the first effort should be a collection of case histories of typical oil ash corrosion incidents that would serve to emphasize certain characteristic features of this type of attack. This is done in this report.

A further purpose of the present paper is to describe the approaches that have been taken to the problem in the past and how successful each has been. Finally from this study it is desired to suggest those lines of effort that appear to be most promising.

### Several Case Histories of Oil Ash Corrosion

#### Case History No. 1<sup>(1)</sup>—TUBE SUPPORTS IN AN OIL FIRED FURNACE

Severe corrosion was observed on tube supports in an oil fired heater with radiant roof tubes. The heater raised the temperature of the oil charge to 670-880 F. The firebox temperature was 1700-1800 F. Thus the heater tube supports were at a temperature where rapid corrosion has been observed to take place.

The fuel was a residual stock containing 4.1 percent sulfur and 0.05 percent ash which analyzed 16.2 percent  $V_2O_5$ . The alloy tube supports were chromium-nickel

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iron alloy castings (25 Cr-12 Ni) used extensively for high-temperature service. The failure of the tube supports took place from an attack which produced a thick scale and a reduction of section which eventually led to cracking and rupturing in a fraction of the normal expected life. However, no attempt was made to establish exact corrosion rates because of the variation in heater operation.

Type 309 stainless steel has been used to repair broken supports. This alloy exhibited a corrosion rate of about 0.5 ipy in this service with the formation of a voluminous exfoliated scale.

The high sulfur and high vanadium content in the fuel are characteristic of this type of corrosion. The chromium-nickel iron alloy, with a good record of service at high temperature, corroded at an accelerated rate.

**Case History No. 2<sup>nd</sup>—RE-RADIATION CONE IN A CIRCULAR BOTTOM-FIRED VERTICAL TYPE OIL HEATER**

The inverted re-radiation cone was suspended in the center of the heater just below the convection section. The tip of the cone was a casting and the rest of the cone was fabricated from wrought alloy plates. Both the cast and wrought material were of the 25 chromium 20 nickel composition. The firing conditions were such that the temperatures on the cone ranged from 1450 F at the tip, down to 1300 F on the cooler portions. The fuel was a high sulfur, high ash residual fuel, with about 15 percent vanadium pentoxide in the ash.

Severe corrosion was observed on the cone. The corrosion rate varied from the tip (1450 F) to the cooler portion (1300 F). Rates at the hotter tip portion were about 0.12 ipy and very slight in the cooler portion. This temperature effect has been observed in other cases and may be termed a characteristic feature of oil ash corrosion.

**Case History No. 3<sup>rd</sup>—TUBES AND TUBE SPACERS IN SUPERHEATER UNIT**

Several cast superheater spacers failed after seven months' service in a power station, generating steam at 1050 F. The spacers were 25 Cr-12 Ni (ACI Type HH). Severe pitting corrosion was observed to have taken place on the 347 stainless tubes. The superheaters at the power station were fired with a Bunker "C" oil from a Venezuelan crude.

The large quantity of corrosion product could be separated readily from the tube spacer revealing large shallow pits and undercutting of the metal. The presence of occasional globules of furnace ash and oxide indicated to those examining the failed spacers that one constituent in the ash was molten at the operating temperature. Metallographic examination of the metal demonstrated that the corrosion had progressed by sulfidation and oxidation.

(1) H. H. Bennett, Socony Mobil Oil Company.  
(2) E. N. Skinner (The International Nickel Company).

**TABLE 1—Furnace Deposit Analyses**

Type of Deposit	MATERIAL CONTAINED (Percent)				
	V	Mg	Na	SO <sub>4</sub>	Fe
Furnace Deposit from Ship B, Boiler No. 1.	23	7	12	24	10
Furnace Deposit from Ship B, Boiler No. 2.	32	8	6	6	16

The furnace ash was analyzed and found to contain about 4 percent vanadium, 8.71 percent sodium, 4.5 percent calcium, and 15 percent sulfur as well as 4.1 percent SiO<sub>2</sub> and 28.4 percent sulfate. Some corrosion product was mixed in with this ash and thus altered the composition somewhat.

**Case History No. 4<sup>th</sup>—INCONEL TUBES IN SUPERHEATER**

A well documented failure from a chemical plant involved Inconel tubes in a bundle for superheating steam to 1300 F. These tubes were 2 inches in outside diameter and 0.2 inches thick. The attack was so severe that this 0.2 inch wall was penetrated during the year of service.

The principal fuel was a low sulfur producer gas. However, 15 to 25 percent of the total heat input was supplied by a Bunker "C" oil. This oil contained 1.0-1.5 percent sulfur.

The severe attack was located in those areas upon which fly ash impinged. Those areas that were masked from direct impingement were relatively free from attack.

Metallographic examination showed that the duplex sulfides of chromium and nickel were formed. The sulfidation was followed by oxidation which destroyed the metal. Analysis of the scale gave a V<sub>2</sub>O<sub>5</sub> content of 0.3 percent. The tube surface that was sheltered, for example by an adjacent tube, was oxidized or sulfided to a considerably lesser depth.

From the study of this field case, it was postulated that the attack was due to the sulfur aided by the vanadium.

**Case History No. 5<sup>th</sup>—FAILED SUPERHEATER TUBE SUPPORT PLATES FROM TWO NAVAL VESSELS.**

Sections were taken from deteriorated tube support plates from three Fleet boiler units and examined by X-ray diffraction, emission spectrograph, and chemical analytical techniques.

Ship A had steamed 35,500 hours. The plate exhibited severe localized erosion and necking down. The corrosion product was a tight red scale.

Ship B had steamed 32,500 hours; specimens were taken from two boilers. The plates had developed cracks and fractures and there was a hard deposit of slagged furnace product adhering to the metal.

These tube support plates were cast 25 Cr-20 Ni steel. Analysis of the failed specimens showed that the steel met specifications.

Furnace deposits gave the analyses shown in Table 1.

The unusually high vanadium contents of these deposits are very apparent. Laboratory examination of the scales showed that the two types of scale, the tight red scale, and the hard slagged product, were very much alike chemically. Both contained the constituents for accelerated oxidation.

**Approaches Taken to Solve the Oil Ash Corrosion Problem**

There have been at least five different approaches to this problem in the past.

1. Oil Treatment
2. Protective Coatings
3. Additives
4. Alloy Selection
5. Design Changes

(3) G. B. Breeden, work from U. S. Naval Engineering Experiment Station—W. J. Greenert.

These will be considered in some detail and an appraisal of how successful these have been in solving the general problem will be made.

**Oil Treatment**

Within the economics of the application the oil may be treated to remove the vanadium, sodium, and sulfur compounds. Unfortunately, the cost of the treating operation has not permitted this approach to furnish a general solution to the problem.

Any oil treatment developed would have to take into account first, the differences in composition of oil from various sources, and secondly the place of usage of the fuel. The vanadium, sodium, and sulfur content may vary greatly in residual oils from Venezuela, the Middle East, the Far East, and the United States. The order of magnitude of these contents might be:

Sulfur	2-4 percent
Vanadium	from 20 to 800 ppm
Sodium	from 10 to 600 ppm

If the oil is finally carried by pipeline or tank car, it may be treated at the refinery to remove some of these corroding agents. In this case the problem is simplified. However, many applications require transport by tanker with the opportunity to pick up salt water enroute.

An example of oil treatment to reduce corrosion is that of the gas turbine installation at the Central Vermont Public Service Corporation at Rutland, Vermont<sup>1</sup>. The purpose of the treatment here is to reduce the sodium salt content of the residual oil. The heated fuel oil is mixed with an emulsion breaker, then with a solution of magnesium sulfate and the mixture centrifuged. The magnesium sulfate solution is used to achieve a density difference required to get good separation during centrifuging. Also the magnesium salt that remains in the oil functions as a desirable additive. This treatment lowers the sodium and calcium content of the oil. An oil originally containing 70-100 ppm sodium and 200-250 ppm calcium was taken by this procedure to a sodium content of 4-8 ppm and a calcium content 20-30 ppm. An estimated cost for a treatment of this type is \$0.14 per barrel. This would be a limitation on its general applicability.

**Protective Coatings**

The problems involved in the selection of a protective coating are somewhat similar to those associated with the selection of a corrosion resistant alloy. Usually if a single specific corroding agent is operating, it is possible to choose a good protective coating but as the corroding agents multiply the choice becomes more difficult. A further problem is the temperature of operation and the temperature cycling. The temperature is such in most applications that diffusion rates of the elements used for commercial materials are quite high and within a short time the protective character of the coating disappears. The temperature cycling, of course, makes adherence difficult. Chromium plate while satisfactory from a corrosion standpoint separates from stainless steels because of differences in coefficients of expansion<sup>2</sup>. In spite of these difficulties some success has been realized with protective coatings.

In the study of the re-radiation cone<sup>3</sup> described as case history No. 2 above—coated specimens of stainless steel were exposed in the heater near the cone at 1350 F for 335 days along with uncoated

specimens and corrosion rates were measured. The observed penetration rates were:

Type 347 stainless steel (bare) .....	0.032 ipy
Type 347 stainless steel (aluminum coated) ....	0.029 ipy
Duralized 28 chromium 10 nickel alloy .....	0.006 ipy

The Duralized specimen had only a thin coating of scale while the other samples were heavily scaled.

It has been demonstrated that calcium compounds inhibit attack by  $V_2O_5$  when used as fuel additives. Also some experiments have shown that coating tubes in boilers with lime have inhibited attack. This method evidently puts the lime in the right place to react with the vanadium compound when it is deposited.

Conflicting reports have come out on ceramic coatings and the protective qualities of aluminized steel.

Up to the present time the use of protective coatings for parts which would operate in the neighborhood of 1500 F has not proven to be an outstanding solution to the problem. However, it is also true that not much work has been done in this area.

#### Additives

The requirements for a good additive may be listed:

- (1) The additive must combine chemically with the corrosive agents (vanadium, sulfur, sodium) to produce high melting, stable compounds. It has been established that there is a direct correlation between the fusion point of the ash and its corrosivity<sup>4</sup>.
- (2) It must be cheap, (an estimated cost ranges from \$0.001/gallon for central station boiler to \$0.04/gallon for a gas turbine<sup>5</sup>).
- (3) It must be commercially available, obtainable in car load quantities.
- (4) It probably should have a cation of low atomic weight. Experience has shown that most of these additives function on an atom ratio, (i.e., by chemical reaction.) Thus, for a given atom ratio, the lower the atomic weight, the lower the actual weight of additive needed.
- (5) The additive must be easily introduced into the system. If it is a slurry it should not cause excessive wear on pumps or cause clogging of nozzles.
- (6) It should function for the alloys in the system. It has been observed that certain additives have retarded corrosion on 25 chromium-20 nickel steel but not on Croloy compositions<sup>6</sup>.

In the search for the best additive, compounds of Al, Ni, P, Ba, Ca, Cu, Mg, Si, Zn, Na, Mn, Cd, Pb, B, K, Li, Sr, Sb, Zr, Sn, Cr, Ti, and Fe in the form of oxides, carbonates, or sulfates have been investigated<sup>7,8</sup>.

Generally speaking, the compounds of Mg, Ca, Zn, P, and Al have been found most effective with not much general or specific agreement among investigators. For example, in some studies aluminum appears to have been an effective agent<sup>9</sup>, in others, ineffective<sup>7</sup>. In gas turbine operation the deposit problem is closely connected with the corrosion problem, and in fact, may dictate what may be used as an additive to inhibit corrosion. In this connection aluminum silicates have been found to decrease the amount of ash and

make for a more powdery and less adherent deposit<sup>9</sup>. The addition of Ca compounds may actually increase attack on certain alloys<sup>8</sup>.

The divergence of results is no doubt associated with the conditions of testing. For example, not only the temperature of testing but also the alloy employed in the test may influence results. The effectiveness of many inorganic compounds in reducing the corrosion of an iron base alloy and a nickel base alloy were measured at two temperatures and listed in the decreasing order of effectiveness with the results shown in Table 2<sup>1</sup>.

The efficiency of these additives also vary with the sodium and sulfur content of the fuel.

That the order of effectiveness should change with temperature is not too surprising<sup>7</sup> because the relative effectiveness of a group of additives must be related to the stability of their compounds, the order of which may change with temperature. In these residual oils there is usually 2-4 percent sulfur, so during combustion the sulfate of the metal additive is formed. If the relative effectiveness of calcium and barium as additives for vanadium corrosion were to be considered it would be necessary to study the stability of their sulfates and the vanadates. Calcium sulfate is less stable than barium sulfate so as a first estimate one would expect a greater tendency for calcium to form a vanadate and thus for calcium to be a better inhibitor.

The use of magnesium may be cited to illustrate current commercial practice in utilizing an inorganic additive to retard corrosion. The magnesium is added to the oil, as the oxide or sulfate, as a very fine powder of controlled particle size, or as an aqueous suspension. The attempt is made to maintain a Mg/V ratio of about 3 to 1. This practice has been successful in gas turbine operation and in central station boilers.

#### Alloy Selection

In choosing an alloy for service in a given corrosive environment the best success has been realized when a single specific corroding agent has been involved. It even has been possible to so alter the composition of known alloys that a structure resistant to the single chemical species is obtained. However, in the oil ash corrosion problem a more complex situation exists. Vanadium is present in the oil as an oil soluble porphyrin<sup>10,11</sup> that is converted to  $V_2O_5$  upon combustion. Sulfur is present as inorganic and organic sulfur compounds that are converted to sulfates; sodium exists, initially as sodium chloride and finally as sodium sulfate, sodium oxide, or some complex. All of these interact to yield an extremely corrosive environment.

First, consider sodium sulfate. This compound, by itself is not particularly corrosive to stainless steels such as Type 310 or 304 or even Mo containing steels. However, if there are reducing agents present attack is very rapid—perhaps completely destructive. It seems reasonable to accept the explanation that postulates that the lower valent sulfur, produced by the reducing environment, acts on the alloy to form a liquid metal-metal sulfide eutectic, which penetrates the alloy, dissolves the metal and renders it susceptible to oxidation.<sup>12</sup>

$V_2O_5$ , by itself, is quite corrosive, probably because it fluxes protective oxide films and allows supposedly heat resistant alloys to oxidize at a rate characteristic of the bare metal. It is

also possible that  $V_2O_5$  functions by its well known catalytic behavior or by building, along with the alloy, an oxide film particularly receptive to diffusion. Several high nickel alloys, like Inconel and Inconel X, are quite resistant to attack up to 1500 F (815 C), as are the chromium-iron alloys, Type 446 and Hoskins No. 10.<sup>13</sup> Apparently in chromium-nickel alloys a certain minimum nickel content is required. In a study of several alloys under comparable conditions it was observed that a 78 percent Ni, 20 percent Cr composition and a 63 percent Ni and 14 percent Cr composition were not attacked while a 50 percent Ni, 20 percent Cr was attacked.<sup>13</sup> Mo containing alloys are attacked quite severely by  $V_2O_5$ . The addition of silicon to the alloy or to the surface by a siliconizing treatment improves the resistance of chromium alloys to molten  $V_2O_5$  and oxygen up to 1695 F (925 C).<sup>14,15</sup>

Thus it may be concluded that if sodium sulfate or vanadium pentoxide were encountered separately an alloy could be produced to furnish the desired corrosion resistance. However, in practice, mixtures of these two species are encountered that act in a manner that is more than additive. A particularly corrosive mixture contains 85 percent  $V_2O_5$  and 15 percent  $Na_2SO_4$ .

The actual constituents present in various mixtures of sodium sulfate and vanadium pentoxide have been investigated with the conclusions that:<sup>16</sup>

1.  $Na_2SO_4$  exists only in mixtures containing less than 56 percent  $V_2O_5$ .
2.  $SO_3$  is liberated from all mixtures, partially up to 56 percent  $V_2O_5$ , and completely beyond 56 percent  $V_2O_5$ .
3. The 56 percent  $V_2O_5$  mixture consists entirely of  $NaVO_3$ .
4. The 80 per cent  $V_2O_5$  mixture consists entirely of the  $Na_2O \cdot 3V_2O_5$  complex.
5. The 88.8 percent  $V_2O_5$  mixture consists entirely of the complex,  $Na_2O \cdot V_2O_4 \cdot 5V_2O_5$ .
6. Free  $V_2O_5$  exists only in mixture containing in excess of 88.8 percent  $V_2O_5$ .

The most corrosive mixture is that containing about 15 percent  $Na_2SO_4$ , remainder  $V_2O_5$ . The explanation that the oxygen absorbing capacity which also exhibits a maximum at this percentage is the determining factor in the corrosivity of these mixtures<sup>17</sup> appears logical. The rate determining step in the oxidation process is the rate at which oxygen passes through the molten film. In the film, because of the high absorbing capacity of these mixtures there exists a plentiful supply of oxygen. This amounts to the oxide film, which normally acts in a protective manner, simply being a reservoir of the corroding agent.

Metallographic examination of many specimens that have failed in the field

TABLE 2—Arrangement of Inorganic Compounds in Decreasing Order of Effectiveness in Reducing Corrosion

IRON BASE ALLOY		NICKEL BASE ALLOY	
1450 F	1600 F	1450 F	1600 F
Magnesium	Calcium	Phosphorus	Zinc
Zinc	Magnesium	Zinc	Calcium
Phosphorus	Phosphorus	Calcium	Magnesium
Calcium	Zinc		Phosphorus



point out quite well that the failure often is caused by more than one agency. The corrosion may proceed by sulfidation and oxidation with the formation of nickel, chromium, or iron sulfides, or their mixtures.

In actual practice alloys such as 25 percent Cr, 20 percent Ni iron base alloy or Inconel are used. Such alloys are known to perform well under normal high temperature applications. But it is generally recognized that no alloy has shown, thus far, to have the ability to offer excellent resistance to oil ash corrosion in the 1600-1800 F range.

#### Design Changes

Like all chemical reactions, oil ash corrosion increases in severity with increased temperature. Some results obtained with an iron base (17 percent Cr and 18 percent Ni) alloy may be cited.<sup>1</sup> At 1200 F a loss of weight of 2 mg/cm<sup>2</sup> was observed and at 1600 F, 92 mg/cm<sup>2</sup>. Above 1200-1300 F, where V<sub>2</sub>O<sub>5</sub>, or other mixtures sinter and melt, corrosion is intensified. If through design changes the temperature of continual operation of critical parts can be maintained below 1200 F the situation will be improved.

Studies have been made in laboratory combustion rigs of the influence of the air:fuel ratio on corrosion.<sup>2</sup> Down to a ratio of 20:1 the corrosion rate was not affected provided that the temperature was maintained constant. Below this point corrosion was reduced to a low figure at the theoretical ratio. At ratios less than theoretical the corrosion is due to sulfidic type of attack. The lower corrosion at the lower ratios<sup>3,9</sup> is explained by the formation of V<sub>2</sub>O<sub>5</sub> or V<sub>2</sub>O<sub>4</sub> rather than V<sub>2</sub>O<sub>3</sub>. These lower oxides of vanadium are higher melting than V<sub>2</sub>O<sub>5</sub> and tend to be carried through the system as harmless dust.

Through equipment design and operation it seems reasonable to use this behavior to improve the picture.

As mentioned before the corrosion problem is tied quite closely to the deposit problem in gas turbine operation. Considerable improvement may be achieved in the latter when the machine is operated intermittently. Upon cooling, deposits may flake off and no longer cause corrosion difficulties.

There is some experience which indicates that with improved draft more of the harmful deposits can be carried through and out of the system. Less deposit will reside in the parts operating at high temperature and less corrosion will be experienced.

#### Future Work

There appear to be several lines of effort that offer some promise. Some of these are being worked on now by members of the committee or others concerned with this problem.

1. In the additive field the development of oil "soluble" compounds and their distribution in oil at the refinery seems promising. The suspension of additives with ultrafine and controlled particle size to yield a stable dispersion is feasible.

2. Treatment of the oil to lower the sodium content is a practical (although costly by some standards) operation. In recent years the technique of solvent extraction has progressed considerably. The extraction and recovering of vanadium might be developed to a practical operation. Such a treatment would have to carry the vanadium content down to about 10-20 ppm.

3. While alloy development does not appear to be a promising approach some studies have demonstrated that many oxides do not react with V<sub>2</sub>O<sub>5</sub>, (i.e., are

poor additives to inhibit V<sub>2</sub>O<sub>5</sub> corrosion.) Conversely, if these oxides are formed on an alloy they would not be affected by V<sub>2</sub>O<sub>5</sub>. Alloys which might form these oxides would be quite resistant to corrosion. It should be kept in mind, however, as emphasized above, that the alloy must be resistant in mixtures and complexes rather than the individual species Na<sub>2</sub>SO<sub>4</sub> and V<sub>2</sub>O<sub>5</sub>.

4. Some results have been obtained with aluminized and siliconized steel that would encourage further examination of this means of protection.

5. Finally, the basic work that will result in a better understanding of the mechanism of reactions will help bring about a solution to this problem.<sup>10,17</sup>

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# NACE TECHNICAL COMMITTEE REPORT

## Tentative Recommended Specifications for

## Asphalt-Type Protective Coatings For Underground Pipe Lines

### (Minimum Recommended Protection)

### A Report of NACE Technical Unit Committee T-2H

### On Asphalt Type Pipe Coatings

**Scope:** The minimum recommended protection of buried steel pipe lines against soil corrosion should not be construed as a standard, or as limitation on more effective means to obtain such protection. Each pipe line installation should be engineered so that the excellence of the pipe coating at all times is consistent with the hazards resulting from corrosion damage and with the designed life of the pipe line facilities. The purpose herein is to establish a limit below which it is doubtful (based upon engineering knowledge and experience) that adequate corrosion protection is obtained. NACE Unit Committee T-2H Tentative Recommended Specifications for *Wrapped Systems* and *Mastic Systems* define pipe coatings to use when more than minimum protection is required.

#### Section 1—Description

**1.1** The asphalt wrapped system for pipe lines as a minimum shall consist of a prime coat followed by an application of asphalt enamel in conjunction with a layer of reinforcing or protective wrapping. When extra protection is required, additional layers or thicknesses of enamel and wrapping shall be applied. (See Unit Committee T-2H Tentative Recommended Specifications for *Wrapped Systems*.)

**1.2** The wrapping system shall as a minimum conform to the type specified below:

#### Single Wrap System

- 1 coat of asphalt primer
- 1 coat of hot asphalt enamel  $\frac{3}{32}$ -inch  $\pm \frac{1}{32}$
- 1 wrap of asphalt-saturated felt or asphalt-saturated glass wrap completely bonded to the enamel.
- or
- 1 coat of asphalt primer

#### Abstract

Recommended minimum characteristics of an asphalt wrapped underground pipe line coating system are given. Included are physical characteristics of primer, enamel and wrapping, testing methods for primer and enamel.

- 1 coat of hot asphalt enamel  $\frac{3}{32}$ -inch  $\pm \frac{1}{32}$ —Grade B
- 1 wrap of glass mat (embedded in coating)

#### Section 2—Materials

**2.1 Primer**—The primer shall be composed of a petroleum asphalt base and petroleum solvents, suitably blended to produce a liquid coating which may be applied cold by brushing or spraying and which will produce a suitable bond between the metal and the asphalt enamel. The primer shall have good spraying, brushing and leveling properties and a minimum tendency to produce bubbles during application. It shall be homogeneous, free from water and shall meet the following requirements:

Flash point (open tag), °F, min.....100

Furol viscosity at 77° F, sec.....30-150

#### Distillation:

Distillate (percent of total distillate to 680 F)

To 374 F, min.....	35
To 437 F, min.....	75
To 500 F, min.....	87
To 600 F, min.....	97

Residue from distillation to 680 F, volume percent by difference.....30-45

#### Tests on residue from distillation:

Softening point (ring and ball), °F.....	160-225
Penetration at 77 F (100/5).....	2-25
Solubility in CCl <sub>4</sub> , percent, min.....	99.0

**2.2 Asphalt Enamel**—The asphalt enamel shall be composed of petroleum asphalt combined with appropriate inert mineral fillers. It shall be uniform in character, free from water and shall not



foam when heated to 400 F. It shall meet the following requirements for the grade selected by the engineer when tested in accordance with the methods hereinafter enumerated:

Grade	A	B
Softening point (ring and ball), °F . . . . .	210-240	240-260
Penetration at 77 F, 100 g, 5 sec, max. . . . .	14	7
Penetration at 115 F, 50 g, 5 sec, min. . . . .	5	3
Flash point (Cleveland open cup), °F, min. . . . .	450	450
Loss on heating at 325 F, 5 hours, percent, max. . . . .	0.5	0.5
Ash, weight percent. . . . .	10-40	10-40
Settlement (ratio of ash in bottom half to ash in top half after 5 hours at 400 F), max. . . . .	2:1	2:1
Flow Resistance:		
Penetration at 85 F, 100 hours, inches max. . . . .	0.02	0.01
Penetration at 115 F, 6 hours, inches, max. . . . .	0.04	0.02
Electrical resistance, salt water immersion, 7 days, megohms/ft <sup>2</sup> , min. . . . .	1000	1000

**2.3 Pipe Line Wrapping**—The pipe line wrapping shall consist of asphalt saturated rag or asbestos felt and either unsaturated or asphalt-saturated bonded fibrous glass mats as specified by NACE Unit Committee T-2J. Paper as may be used for outside wrap shall consist of 60 lb., 100 percent sulfate, smooth, unsaturated Kraft.

**2.4 Approval of Materials**—Prior to use, samples of all materials proposed to be used under these specifications shall be submitted to the engineer for test and analysis and no material shall be used until it has been approved by the engineer.

**2.5 Methods of Testing**—Except as otherwise noted, methods of testing shall be the latest revision of methods adopted by the American Society for Testing Materials.

#### *a. Asphalt Primer*

Flash Point—Method of test approved by Bureau of Explosives, AASHO method of test T79

Viscosity—ASTM method of test D88  
Distillation—ASTM method of test D402

Penetration—ASTM method of test D5  
Softening Point—ASTM method of test D36

Solubility in carbon tetrachloride—ASTM method of test D4, except that

CCl<sub>4</sub> is used instead of CS<sub>2</sub> as solvent, Method No. 1.

#### *b. Asphalt Enamel*

Softening Point—ASTM method of test D36

Penetration—ASTM method of test D5

Flash Point—ASTM method of test D92

Loss on heating at 325 F—ASTM method of test D6

Ash—ASTM method of test D271

Settlement—See NACE Unit Committee T-2H Wrapped Systems Specifications

Flow Resistance—See Unit Committee T-2H Wrapped Systems Specifications

Electrical Resistance—See Committee T-2H Wrapped Systems Specifications

### **Section 3—Construction**

See NACE Unit Committee T-2H Tentative Recommended Specifications for Wrapped Systems.<sup>1</sup>

### **Section 4—Cathodic Protection**

See NACE Unit Committee T-2H Tentative Recommended Specifications for Wrapped Systems.<sup>1</sup>

### **Section 5—Maintenance**

See NACE Unit Committee T-2H Tentative Recommended Specifications for Wrapped Systems.<sup>1</sup>

#### **Reference**

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# Zinc as a Cathodic Inhibitor\*

By HANS B. JONASSEN

## Introduction

**M**OST CORROSION inhibitors used at the present time such as phosphates, carbonates, or chromates are reasonably efficient. It must be remembered however that they are anodic inhibitors and form insoluble precipitates with the oxidized ferrous or ferric ion. Such compounds may not function as inhibitors if they are present in inadequate concentrations, especially if the solution also contains chloride or sulfate ions. Under these conditions they may severely localize corrosion and actually enhance the severity of the attack. Perforation of plates thus may occur more rapidly in the presence of the inhibitor than in its absence as was demonstrated by Evans.<sup>1</sup>

This difficulty does not exist with cathodic inhibitors even when they are added in insufficient amounts. Examples of cathodic inhibitors are such metal ions as zinc or nickel which form insoluble or sparingly soluble hydroxides. These insoluble metal hydroxides are deposited on the cathodic zone and retard the oxidation of the iron in such neutral or slightly basic solutions. Evans,<sup>2</sup> for example, found that zinc sulfate solution produced less corrosion than the water from which the solution was prepared and much less than a drop of sodium sulfate added to this water. A darkish precipitate formed indicating either that the active spots where cathodic reaction occurs had been covered or that the precipitate decreased the diffusion of oxygen necessary for the cathodic reaction. A similar effect was observed when<sup>3</sup> precipitated zinc hydroxide on iron was found to retard corrosion considerably. Similar results also were observed by Kahler and George.<sup>4</sup>

It should be noted, however, that the addition of soluble zinc salts has one major drawback: the salts contain anions (chlorides, sulfates, and nitrates) which increase corrosion. For that reason it would be advantageous if metallic zinc could be oxidized in water solution to give the zinc ions which produce cathodic inhibitors without giving the objectionable anion.

## Results and Discussion

### Oxidation of Zinc

Slow oxidation of zinc will occur in water and its rate of oxidation can be increased by increasing the temperature. Another way of increasing the corrosion rate of zinc is to decrease its extremely high overvoltage.

It is well known that the high overvoltage of metals may be reduced by the addition of impurities. An investigation of the effect of impurities on the overvoltage of zinc was made by Vondracek and Izak-Krizko.<sup>5</sup> A similar reduction of the overvoltage occurs when



About  
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Author

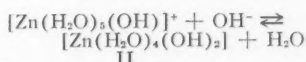
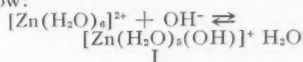
HANS B. JONASSEN received his PhD from the University of Illinois in 1946, and is now Professor of Inorganic Chemistry at Tulane University in New Orleans, Louisiana. He is also a consultant for Esso Standard Oil Company and the Ordnance Departments of the Army and Navy. Dr. Jonassen's main professional interest has been in the field of complex ions as related to fundamental problems in inorganic, organic, physical, electrochemical and many other fields of chemistry.

metals such as zinc are placed in very close and tight contact with a more noble metal with a very low overvoltage. Straumanis investigated this phenomenon for several metals with high overvoltage and found that their corrosion rate increased when in contact with the following noble metals: silver, copper, gold and platinum.<sup>6</sup> Several methods of producing close contact between the two metals were investigated. It was found that the best lowering of overvoltage was obtained when a silver or platinum wire was wound tightly around a zinc rod. For most of this work a silver wire was used. This produced a sufficiently high concentration of zinc ions at the three temperatures (25, 35, and 45 C).

### Investigation of Zinc Complexes

When cathodic inhibitors are present in solution it becomes interesting to determine their stereochemical configuration. This is especially true if the inhibitor has to be solubilized before it can act.

When its overvoltage has been lowered, zinc in water solution reacts with the hydrogen ion from the water to give hydrated zinc ions which then can react with hydroxide ion present at the surface of the metal to give a series of postulated products which are shown below:



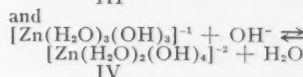
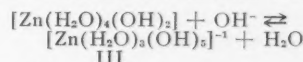
If the concentration of zinc ion becomes too high at the surface, zinc hydroxide(II) will precipitate and form a surface film. However, in a flowing sys-

## Abstract

It was shown that zinc metal in close contact with a noble metal such as silver furnishes zinc ions to an aqueous solution. A binuclear zinc hydroxide complex cation seems to be formed which can act as a cathodic inhibitor. This ion also acts as a buffer removing  $\text{CO}_2$  and it reacts with the oxygen in the water to give additional hydroxide ions.

Considerable attention is given to the investigation of the nature of zinc complexes. Other topics discussed include nature of the cathodic protective coating forming on zinc, effect of the addition on impurities to zinc, and peptizing effect of the zinc hydroxide complex. 5.8.4

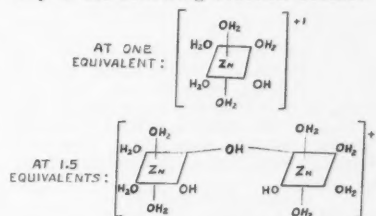
tem or in one being stirred, the zinc complex species(I) would be removed and then could act as cathodic inhibitors. In the presence of excess hydroxide ions two further reactions can occur:<sup>7,8</sup>



Where (IV) is the well known zincate ion.

It was of interest, therefore, to investigate the particular species present in such zinc ion solutions which acted as a cathodic inhibitor. The system was investigated by potentiometric and conductometric titration methods.

As Figure 1 indicates when a dilute solution containing hydrated zinc ions is titrated with hydroxide ions three breaks are observed in the curve, the first at one equivalent of hydroxide ions, the second at 1.5 and an isoelectric point at 2 equivalents. This can be explained only if the following reaction occurs:



As can be seen at 1.5 equivalents, a binuclear complex bridged by a hydroxide ion is formed. Similar binuclear complex ions have been found by Jonassen and Strickland<sup>9</sup> to exist in slightly basic water solutions of transition metal complexes.

The addition of further hydroxide ions leads to the precipitation of zinc hydroxide, as the third break on the curve. Further addition of hydroxide ions brings about the formation of zincate complexes (a development, however, which cannot occur under the conditions of these experiments). Measurements on these solutions indicate that the binuclear zinc complex ion exists at a pH of 7.8-8.5 at 25 C in this very low concentration range.<sup>7,8</sup> This is also the pH produced when zinc metal with low over-

\* Submitted for publication July 22, 1957. A paper presented at a meeting of the Northeast Region, National Association of Corrosion Engineers, Syracuse, New York, May 20-22, 1957.

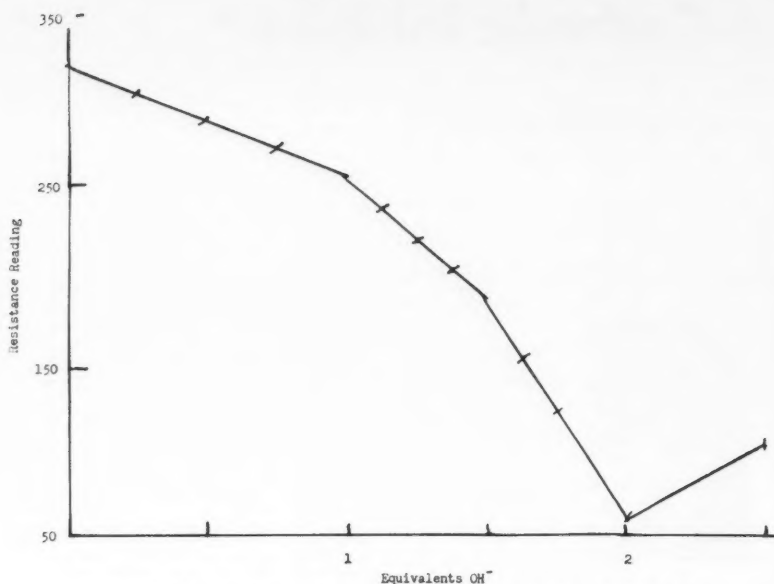


Figure 1—Conductometric titration of 50 ml of 0.001 M solution of  $Zn^{+2}$  with 0.1 M NaOH.

voltage is in equilibrium with a stirred aqueous solution at that temperature.

The binuclear zinc complex cation can react with the hydroxide ion produced on the oxidized iron surface to give the insoluble hydroxide precipitate. This will then cover the active spot where the cathodic reaction would occur, bringing about cathodic inhibition.

#### Buffer Action

Since the binuclear zinc complex exists between the pH of 8 and 9, it was decided to determine its buffer action. It was diluted to ten times its volume without detectable change in pH.

Next  $CO_2$  was bubbled through the solution in the presence of calcium ions. A very flocculent precipitate of calcium carbonate formed; it was flocculent because of the well-known peptizing effect of the zinc hydroxide complex.

#### Removal of Oxygen

It is well known that the presence of oxygen increases the corrosion rate of zinc,<sup>10</sup> producing both the zinc ions and the hydroxide ions necessary for the formation of the zinc hydroxide cationic complex. At the same time, however, oxygen is removed very effectively from the solution.

#### Nature of the Cathodic Protective Coating

In order to determine the nature and composition of the protective coating, the surface film was stripped and dried

to constant weight at 110 C. Unfortunately, however, X-ray powder-pattern of the surface coating showed only that it was amorphous.

An attempt was then made to produce crystalline material by heating the solid at 600 C for several hours in the absence of oxygen. Under these conditions some sintering occurred and the powder-pattern indicated better than average crystallinity. It also showed that some of the material was the normal zinc ferrite spinel.

Although it seems possible that a certain amount of ionic diffusion may have occurred during the formation of the surface coating, this does not prove that the stable zinc ferrite spinel forms at the surface at low temperature. The higher temperatures used during the sintering operation naturally produced a very large increase in ionic mobility which may have been necessary to form the zinc ferrite indicated in the powder-pattern.

#### Use of Alloys

As has been mentioned above, the overvoltage of zinc also can be lowered by the addition of small amounts of impurities. Metals or metalloids such as tungsten, molybdenum or vanadium, if added in small amounts should lower the overvoltage and increase corrosion of zinc, especially if oxygen is present in the solution.<sup>11</sup>

The introduction of the anions of the

oxyacids of these metalloids may help to remove ions such as the silicate ions which with molybdate, for example, form the so-called heteropoly acid-silico molybdic-acid effectively removing the silicate ion from the solution.

#### Interferences

In order that the oxidation of zinc to zinc ion and then to the zinc hydroxide complex can occur, it becomes important that no anions be present in the solution which will give very insoluble zinc salts. Ions such as phosphate and chromate must be absent from the solution so that the metal will not be inhibited.

#### Experimental

##### Conductometric Titrations

Fifty ml of a 0.001 M solution of zinc ion was titrated with a solution 0.1 M in sodium hydroxide using the conductivity bridge Type R C, Industrial Instruments Inc., Cedar Grove, N. J. and a Sargent conductivity cell dip type.

##### Potentiometric Titration

A Beckman Model G pH meter was used to titrate solutions similar to that in conductometric titrations.

##### Temperature Control

All titrations were conducted in constant temperature baths regulated at  $25 \pm .1$ ;  $35 \pm 0.1$ ; and  $45 \pm 0.1$  C.

##### X-Ray Powder-Patterns

These patterns were obtained using a North American Philips unit with a circular powder camera.

#### Conclusions

It has been shown that zinc metal in close contact with a noble metal such as silver furnishes zinc ions to an aqueous solution. A binuclear zinc hydroxide complex cation seems to be formed which can act as a cathodic inhibitor. This ion also acts as a buffer removing  $CO_2$  and it reacts with the oxygen in the water to give additional hydroxide ions.

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Any discussions of this article not published above will appear in the December, 1958 Issue

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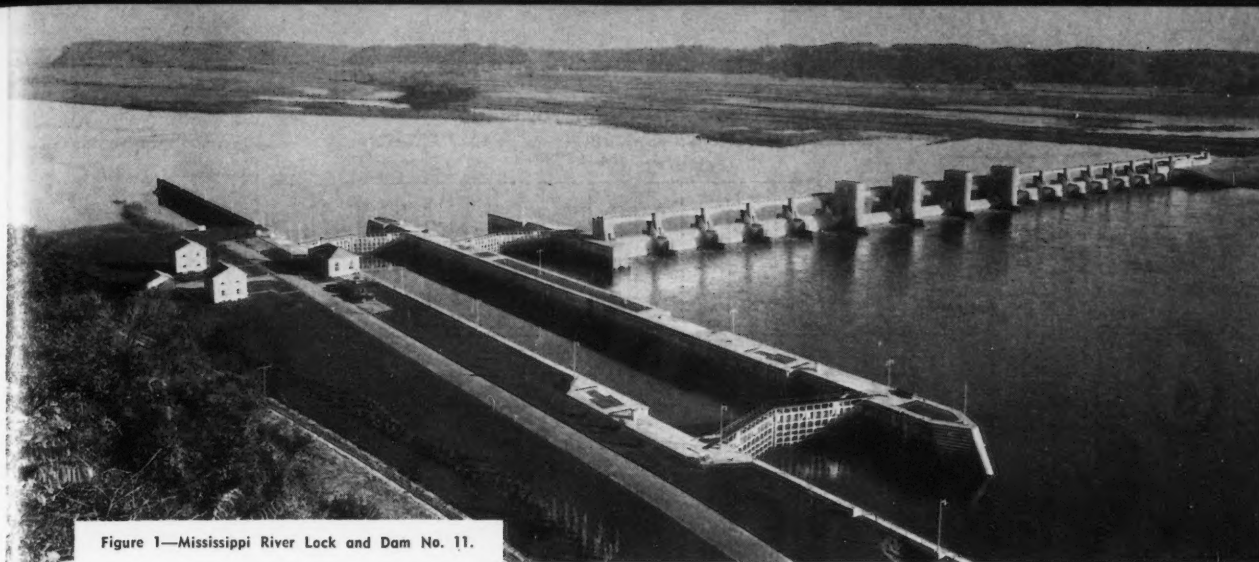


Figure 1—Mississippi River Lock and Dam No. 11.

## Coatings for Underwater Metal Surfaces In Fresh Water Exposures\*

By SOL M. GLESER

### Introduction

**E**NGINEERS ARE only now discovering that there is a science to paints and painting just as there is to any other element of engineering. They are finding out that for successful protection or decoration of metal surfaces, paints, like any other engineering materials must have known properties and characteristics so that their behavior under various conditions can be predicted accurately. The experience of the Upper Mississippi Valley Division, Corps of Engineers, U. S. Army (hereafter referred to as the UMVD) is a case in point.

In the early 1930's the UMVD was given the problem of accelerating the program of channelizing the Upper Mississippi River. This program, now practically complete, comprised the construction of some 26 dams and 27 sets of locks from St. Paul, Minnesota, to the mouth of the Ohio River, together with a new lock and dam at the St. Anthony Falls.

When the program was started, most authorities at that time recommended the use of the then standard practice for protecting steel surfaces, consisting of one coat of 95 percent grade red lead-in-linseed oil paint (weighing about 26 pounds per gallon), and two finish coats of aluminum paint in spar varnish. The prime coat was applied to surfaces from which loose millscale and other foreign materials had been removed by wire brush, scrapers and mineral spirits, with no attempt being made to remove tight millscale. Prime coats normally were applied in the shop, and surfaces marred during shipment and erection were touched up with primer at the site,



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SOL M. GLESER is Director of Field Engineering for A. M. Kinney, Inc., Consulting Engineers, Cincinnati, Ohio. Prior to joining this firm in 1954, he served for 24 years with Upper Mississippi Valley Division, Corps of Engineers, where he was Head of Specifications and Materials Section, and Head of Construction Division. In 1951 he was given a Meritorious Civilian Service Award. Mr. Gleaser received a BS in mechanical engineering from Washington University, St. Louis, Mo. (1929), and an MS in mechanics and mathematics from the same institution (1930). He is a registered professional engineer (Missouri and Ohio) and is chairman of NACE's Southwestern Ohio Section.

after which the two finish coats were applied.

When the gates of the first dam were lifted after having been in water about six months, it was noted that an appreciable part of the underwater coatings had been removed from the surfaces by the erosive action of the silt-laden water flowing over them as well as by floating drift. On underwater surfaces in still water, it was noted that the coatings were soft and could be removed by pressure of the thumb. With such short life, the cost of providing protective coatings for underwater surfaces ap-

### Abstract

A detailed account is given of results of tests made to determine the effectiveness of coatings for underwater metal surfaces on lock and dam components along the upper Mississippi River. Testing periods varied considerably, extending in some cases to as much as 18 years. Data obtained on more than 190 panels are given and results are reported regarding the longevity of various paint systems. Pigmentation formulae, pigment-vehicle ratios and composition of vehicles are given as is surface preparation of panel, coating system used, and life of primer and finish. Topics discussed include preparation of metal surfaces, sand reinforcement, use of multiple paint coats, use of inhibitive primers, intercoat adhesion, suitability of the various vehicles available, use of coal tar and asphalts, use of hot spray metal coatings, thickness of paint films, use of aluminum and use of rubber. 5.4.8

peared to pose a serious economic problem, since it would take between 2 and 2½ years to paint the average dam with the paints and equipment then available.

### Conditions of Exposure

The problem was further complicated by the wide range of exposure conditions. Exposure to ice varies from the frigid conditions near the headwaters of the Mississippi River, where the river is iced to depths as much as six feet with temperatures ranging as low as -20 F, to the comparatively mild conditions near the mouth of the Illinois River where ice conditions occur only sporadically, resulting in many freeze-thaw cycles.

Silt conditions during high water vary from comparatively clear waters near the headwaters to heavy silt loads at Alton, Illinois. Effect of sewage is greater near large cities such as St. Paul and Alton. Action of drift as an abrasive increases with distance downstream, as

\* Submitted for publication April 8, 1957.



TABLE 1—Paint Formulae

Paint Designation	PIGMENTS (Lb.)																			Other Materials
	Vehicle (Gallons)	Added Thinner (Gallons)	Zinc Chromate	Priming Aluminum Paste	Finish Aluminum Paste	Aluminum Powder	Red Iron Oxide	Magnesium Silicate	Talc	Diatomaceous Silica	Asbestine	Ferrabron	Red Lead (Dry)	Litharge (Dry)	Red Lead (Paste)	Chromated Red Lead	Zinc Oxide	Mica	Zinc Dust	
1	.75	0.25	0.7	1.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	1.0	0.45	4.88	2.81	.....	.....	.....	.....	1.63	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	1.0	.....	1.5	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	1.0	.....	3.3	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	1.0	0.39	5.94	.....	.....	3.37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	1.0	.....	1.5	1.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	1.0	0.2	0.95	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	1.0	.....	4.8	.....	.....	.....	1.4	0.7	.....	0.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	1.0	.....	2.0	.....	.....	.....	4.0	1.0	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	1.0	.....	.....	.....	.....	.....	6.0	1.5	.....	0.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10a	1½	.....	.....	.....	.....	.....	6.0	1.5	.....	0.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.0 lb zinc chromate paste per gallon paint (20 percent linseed oil in paste.) 3.0 lb zinc chromate paste per gallon paint (20 percent linseed oil in paste.)
10b	1½	.....	.....	.....	.....	.....	6.0	1.5	.....	0.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	1.0	.....	4.8	.....	.....	.....	1.6	.....	.....	1.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	1.0	.....	3.0	.....	.....	.....	6.0	1.0	.....	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	1.0	.....	1.5	.....	.....	.....	.....	.....	.....	.....	5.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	1.0	.....	6.4	.....	.....	.....	.....	1.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	Proprietary iron-oxide, zinc chromate primer, similar to 10 LTEA																			
16	1.0	.....	1.5	.....	.....	.....	.....	.....	.....	1.6	.....	.....	16.0	.....	.....	.....	.....	.....	.....	.....
17	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.0	100.0	.....	.....	.....	.....	.....
18	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.0	100.0	.....	.....	.....	.....	.....
19	1.0	.....	0.96	.....	.....	.....	0.29	2.2	.....	.....	.....	.....	5.3	.....	.....	.....	.....	0.87	.....	0.03 lb aluminum stearate.
20	1.0	.....	0.78	.....	.....	.....	0.23	1.78	.....	.....	.....	.....	4.3	.....	.....	.....	.....	.....	.....	.....
21	1.0	0.14	.....	.....	.....	.....	.....	1.28	.....	.....	.....	.....	14.65	.....	.....	.....	.....	.....	0.7	0.02 lb aluminum stearate.
22	1.0	.....	.....	.....	.....	.....	.....	.....	.....	1.42	.....	.....	16.25	.....	.....	.....	.....	.....	.....	0.06 lb aluminum stearate.
23	1.0	.....	0.93	.....	.....	.....	.....	1.4	.....	1.4	.....	.....	4.66	.....	.....	.....	.....	0.93	.....	0.05 lb sienna
24	1.0	0.2	.....	.....	.....	.....	.....	1.68	.....	1.68	.....	.....	20.4	.....	.....	.....	.....	.....	.....	0.09 lb aluminum stearate
25	1.0	.....	1.5	.....	.....	.....	.....	2.5	.....	.....	.....	.....	.....	.....	16.0	.....	.....	.....	.....	0.031 gallons pine oil
26	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.9	.....	.....	.....	.....	.....	.....	.....
27	Proprietary red-lead-alkyd primer similar to 31 XM1																			
28	1.0	0.188	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	54.0	.....	.....	.....	.....	.....
29	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.5	.....	.....	.....	.....	.....	.....	18.65
30	1.0	.....	.....	.....	.....	.....	.....	1.4	.....	1.4	.....	.....	21.12	.....	.....	.....	.....	.....	.....	0.09 lb aluminum stearate
31	1.0	.....	0.37	.....	.....	.....	.....	0.75	.....	.....	.....	.....	1.88	.....	.....	.....	.....	0.73	.....	0.07 lb aluminum stearate 0.02 lb aluminum stearate
32	1.0	.....	1.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.5	.....
33	1.0	.....	.....	1.44	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.76
34	1.0	.....	0.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.4	.....	25.0
35	1.0	.....	.....	.....	.....	.....	0.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.4	.....	.....
36	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.5	.....	25.5
37	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.05	.....	22.95
38	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.0 lb chromium oxide 1.15 lb titanium dioxide 1.4 lb Metronite B4X
39	1.0	.....	.....	.....	.....	.....	.....	.....	.....	0.26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
40	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.3 lb zinc tetroxy chromate, 0.1 lb calcium carbonate 6.0 lb metalead paste 6.0 lb metalead paste
41	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6.0 lb metalead paste 3.0 lb blue lead
42	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.15 lb lamp black
43	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.06 lb aluminum stearate
44	1.125	.....	.....	.....	.....	.....	1.5	.....	.....	1.5	.....	.....	.....	.....	.....	.....	2.7	.....	.....	.....

the drift load of each upstream dam is added to the drift brought in from downstream tributaries, until at Alton logs 30 to 40 feet long and 12 to 30 inches in diameter quite often lodge against the upstream faces of the gates or mill in a whirlpool on the downstream sides.

A somewhat clearer picture of the operations and maintenance problems involved may be obtained by reference to Figures 1 through 6.

Figure 1 is an aerial view of Lock and Dam No. 11, a lock and dam unit. It will be noted that the dam is of the navigation type and is comprised of 3 roller gates and 12 tainter gates, surmounted by a structural steel service bridge. Machinery for operating the tainter gates is housed in the bridge while that for operating the roller gates is housed in the small houses surmounting the supporting piers. The lock gates are of the mitering type. The magnitude of maintenance operations can be appreciated from the fact that the average area of ferrous metal surfaces requiring protection in a lock and dam unit is about 750,000 square feet.

Figure 2 is a close-up view of several spans of a typical service bridge (Dam No. 15), and is illustrative of the complexity of the structure relative to provision of protective coatings. Surface to be protected averages about 175 square feet per linear foot of bridge.

Figure 3 is a view of a typical pair of lock miter gates. Note that in order to paint the underwater portion of the gates, it is necessary either to unwater the lock chamber or to remove the gates from the lock to some platform above the water level. Both methods are used as circumstances warrant. Each gate (2 leaves) has about 22,000 square feet of surface to be protected. Note also the walkway on top of the gate, providing access to the river wall of the lock.

Figure 4 is a close-up of a typical roller gate in the raised position, with the opening between piers closed by the gate bulkheads in the background. Note the gate-operating house on top of the pier, the chain for lifting the gate and a portion of the rack up which the gate climbs to reach its raised position.

The riveted construction of the gate and bulkheads is plainly visible. The area to be protected averages about 310 square feet per linear foot of gate. Roller gates in use in the river vary in length from 60 to 100 feet and in height from 20 to 26 feet. More recent design of roller gates provides for all-welded construction. Under normal conditions the flow of the river is either passed under a partly opened gate of the non-submergible type and over a partly depressed gate of the submergible type. In either event, some portion of the gate is subjected to silt-laden water traveling at high velocities, which acts somewhat like a wet sandblast against whatever coatings may be applied to the surfaces.

Figure 5 is a close-up of a portion of a tainter gate in the raised position. Visible also is the lifting chain and a close-up of the underside of the service bridge. As may be noted, the gate and the bridge are of riveted construction. However, the newer types of gates and bridges are now of welded construction. Surface to be protected averages about

TABLE 1—Paint Formulae (Continued)

Paint Designation	Vehicle (Gallons)	Added Thinner (Gallons)	PIGMENTS (Lb.)																Other Materials
			Zinc Chromate	Priming Aluminum Paste	Finish Aluminum Paste	Aluminum Powder	Red Iron Oxide	Magnesium Silicate	Talc	Diatomaceous Silica	Asbestine	Ferrobron	Red Lead (Dry)	Litharge (Dry)	Red Lead (Paste)	Chromated Red Lead	Zinc Oxide	Mica	
15	1.0	....	....	....	....	....	1.25	....	....	....	1.25	....	....	....	....	17.5	....	....	0.06 lb aluminum stearate
16	1.0	....	....	....	....	....	0.84	....	....	....	0.84	....	....	....	....	....	1.12	....	6.72 lb blue lead, 1.68 lb lead silicate
17	1.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	9.9 lb blue lead, 2.48 lb lead silicate
18	1.0	(Same as 31)	1.16	1.03	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.0 lb zinc tetroxy chromate
19	1.0		....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
20	1.0		....	....	....	....	....	....	0.17	....	....	....	....	....	....	....	....	....	
31	36 parts by weight butanol to 6.5 parts 85 percent phosphoric acid																		16.0 lb coal tar, 4.0 lb portland cement
32	1.0	3.0	....	....	....	....	....	....	....	....	....	....	2.18	....	....	....	....	....	
53	....		....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
54	Proprietary vinyl paint similar to 39 XVy1																		-
55	Proprietary processed tar, cold applied																		
56	Proprietary rubber latex paint																		
57	10 parts by volume formula 50 to 4.25 parts formula 51																		
58	1.0	....	2.0	....	1.0	....	4.0	1.0	....	1.0	....	....	....	....	....	....	....	....	
59	Proprietary processed tar, cold applied																		
60	Proprietary processed tar, cold applied																		
71	0.75	0.25	1.5	....	0.7	....	....	....	....	....	....	....	....	....	....	....	....	....	
72	1.0	....	....	....	2.0	....	....	....	....	....	....	....	....	....	....	....	....	....	
73	1.0	....	....	....	1.5	....	....	....	....	....	....	....	....	....	....	....	....	....	
74	1.0	0.2	0.95	....	2.0	....	....	....	....	....	....	....	....	....	....	....	....	....	
75	1.0	....	....	....	....	0.835	....	....	....	....	....	....	....	....	....	....	....	....	
76	1.0	0.2	....	....	....	0.61	....	....	....	....	....	....	....	....	....	....	....	....	
77	Proprietary aluminum-pigmented phenolic-linseed-tung paint similar to 72 LTEA																		12.75 lb white lead, 0.06 lb aluminum stearate, 0.06 lb sienna.
78	1.0	....	....	....	....	1.33	....	....	....	....	....	....	....	....	....	....	....	....	
79	1.0	....	....	....	....	....	6.0	1.5	....	0.5	....	....	....	....	....	....	....	....	
80	1.0	....	....	....	....	....	....	....	....	....	....	7.0	....	....	....	....	....	....	
81	1.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.15	....	
82	1.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	11.2 lb white lead.	
83	1.0	....	....	....	....	....	....	0.58	....	0.58	....	....	....	....	....	0.71	....	0.66 lb chromium oxide, 1.8 lb white lead, 0.01 lb aluminum stearate	
84	1.0	....	....	....	....	....	....	0.75	....	....	....	....	....	....	....	0.25	....	0.03 lb lamp black, 3.0 lb lead titanate	
85	1.0	....	....	....	....	....	....	0.51	....	....	....	....	....	....	....	0.12	....	0.02 lb lamp black, 1.55 lb lead titanate	
86	1.0	....	....	....	....	....	....	0.47	....	....	....	....	....	....	....	....	0.11	0.02 lb lamp black, 1.43 lb lead titanate	
87	1.0	....	....	....	....	....	....	1.01	....	....	....	....	....	....	....	0.25	....	0.04 lb lamp black, 3.02 lb lead titanate	
88	1.0	....	....	....	1.44	....	....	....	....	....	....	....	....	....	....	....	....	5.76	
89	Proprietary aluminum pigmented-vinyl paint similar to 78XV2																		0.04 lb lamp black, 3.1 lb lead titanate
90	Proprietary processed tar, hot applied																		
91	1.0	....	....	....	....	....	....	1.04	....	....	....	....	....	....	....	....	0.26	....	
92	1.0	0.25	....	....	0.6	....	....	....	....	....	....	....	....	....	....	....	....	....	

\* Unpolished

150 square feet per linear foot of gate. Tainter gates vary in length from 35 to 80 feet and in height from 15 to 30 feet, and are of either the submergible or non-submergible type. As is the case for the roller gates illustrated in Figure 4, the gates are subjected to silt-laden water traveling at high velocities. Also, in order to paint the gate, it is necessary to bulkhead off the opening by bulkheads similar to those shown in Figure 4.

Figure 6 is a view of the downstream side of a typical tainter gate (Dam No. 26), partially opened in regulating position. Note the drift lodged in the gate and the whirlpool action of the water bringing the drift and suspended silt into abrasive contact with the gate surfaces. This is typical also of the roller gates.

There was practically nothing in the literature available in 1936, at the time the extent of the problem became apparent, to serve as a basis for its solution. The desired answer to the maintenance problem posed by the conditions described was a system of coatings which had maximum life (to reduce the interval between recoatings) and which required minimum drying time between

coats and prior to immersion (to reduce the overall time of application per gate).

#### Test Procedure

The question was resolved by methodically applying various paints under controlled conditions of surface preparation and application directly on surfaces of selected locks and dams remote from populous centers and then gradually "separating the sheep from the goats." Panels 5 feet wide were painted around the perimeter of selected gates so that some portion of each panel would be subjected to the major types of exposures normally experienced by the structure (to wit, atmospheric, water line (alternate wet and dry), totally submerged, and high water velocities). In addition, thousands of small coated panels also were subjected to accelerated and non-accelerated tests and results compared with field tests.

The purpose of this article is to record the test coatings applied to underwater surfaces of gates in the Mississippi River up to 1947 and the results of exposure to date. These data are listed in Tables 1, 2, and 3. Results of tests

on coatings applied subsequent to 1947 are not given since the writer is not personally acquainted with those subsequent test coatings.

Table 1 lists pigmentation formulae of the various paints and the pigment-vehicle ratio. Each different formula or proprietary paint is designated by a number.

Table 2 lists the various vehicles used and their composition. Resin numbers listed are Bakelite unless otherwise designated. Vinyl designations are those of Carbon and Carbide Corporation unless otherwise shown. Each vehicle is designated by a combination of letters and numbers. The first letters identify the oils used, such as T for Tung, L for linseed, etc. If the vehicle is a synthetic, the letter X so designates it.

The second group of letters designate the resins used such as Z for BR 1329, E for BR 254, M and L for dispersion resins, K for alkyd, etc. The last letter, when used with an oleoresinous paint, designates the oil length (A for 33 gallon length, B for 25 gallon, D for 12½ gallon, and Y for all others). A lower case "n" after a letter designating an oil

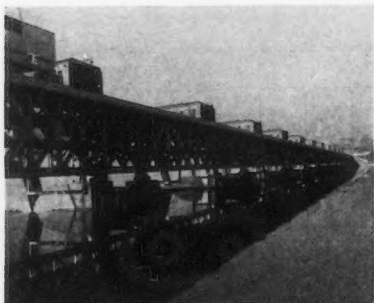


Figure 2—Service bridge at Mississippi River Dam No. 15.

indicates a natural oil unreinforced with resin.

A number after the vehicle designation serves to differentiate between two vehicles composed of the same oils, resins, and oil length. As an example, vehicle LCOEB 1 is a vehicle composed of linseed, dehydrated castor and oiticica oils reinforced with resin BK 254 to 25 gallon length but which is somewhat different in proportions from vehicle

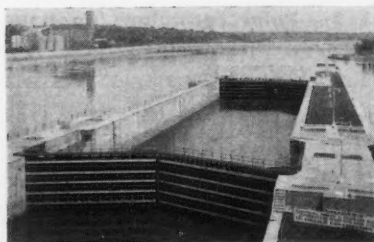


Figure 3—Lock miter gates with water at lower pool (Mississippi River Locks and Dam No. 15).

LCOEB; vehicle XK1 is an alkyd vehicle with no oils.

Table 3 lists the data pertinent to the various systems tested. The first column, titled Ref. No. is provided for ready reference in the discussion. The next three columns are to identify the location of the test panel. In column titled "Surf. Prep," are listed two-digit numbers designating the methods used to prepare the surface. The first digit identifies the method of cleaning as follows:

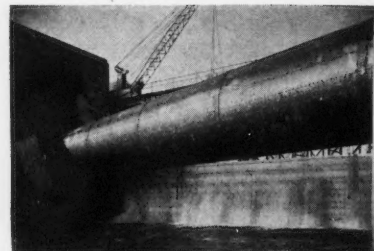


Figure 4—Roller gate in raised position behind bulkheads (Mississippi River Dam No. 15).

- #0 Not cleaned
- #1 Sandblast
- #2 Showerblast\*
- #3 Power Wire Brush
- #4 Other

The second digit identifies the metal treatment as follows:

- #0 No treatment
- #1 Chemical inhibitor
- #2 Vinyl wash primer
- #3 Others

\* Showerblast is a light sandblast sufficiently strong to remove most surface contaminants but not strong enough to etch the metal.

TABLE 2—Vehicles and Their Composition

		OILS (Gallons)										RESINS									
Vehicle Designation	Non Volatile %	Tung	Linseed (Natural)	Linseed (Refined)	Castor (Dehydrated)	Oiticica	Soybean	Castung	Fish Oil (Celestrol)	Resin (lb.)	BR-254 (Lb.)	BR-1329 (Lb.)	BR-4036 (Lb.)	BR-9432-(Lb.)	BR-2963 (Lb.)	BK-3962 (gal.)	XK-15747 (gal.)	Dex 550 (lb.)			
Material Design		J	Ln	L	C	O	S	Ct	F	Nr	E	Z	D	B	A	M	L	G			
TZC	50-55	50																			
TZFA	50-55	33																			
TZEB	50-55	25									25	75									
TDB	50-55	25											100								
TDA	50-55	33																			
TED	50-55	12½									100		100								
TGY	50-51	39								6								100			
TFD	50-55	12½																			
LTEB	50-55	12½		12½							100										
LTBE	50-55	15		10							100										
LTLE	50-55	19		6							100										
LTNB	50-55	20		5																	
TCEB	50-55	12½			12½						100										
LCOEB	58			10	8	7					100										
TZA	50-55	33									100										
LCFEB	50-55			9.9	7.9				7.2			100									
LCEBB	50-55			9.9	7.9				7.2					100							
LBNcY	50-55			6										50							
LEB	55			25							100										
LBB	55			25										100							
OSNbB	50-55					20	5														
LSBY	50-55			5			5								100						
CEB	55				25						100										
CBB	55				25									100							
COAA	50				30	3									100						
XM1	18															10					
XL1																	5				
XK1																					
XK2																					
XVym1																					
XVym2																					
XVy1																					
XVy2																					
XVx																					
XVa																					
Ln			1																		
XN																					
XL2																					
XM2																	42	40			
XL3																		44			
LCOEB1	53			10	8	7					100										
LBKNe	50			9.1				.47						9.75							
LSBK	50													9.4							
TCEM	30	3.35			3.35						26.8					29.5					





TABLE 3—Longevity of Paint Systems in Underwater Exposures

Ref. No.	LOCATION			Surf. Prep.	SYSTEM (Coats)				Date Appl.	LIFE (Yrs.)		Remarks
	L/D No.	Gate No.	Panel No.		1 st	2 nd	3 rd	4 th		Prim.	Finish	
Tung Oil + Resin D												
1	5	*	*	10	16TDB	72TZE	72TZE	.....	7/38	16	10	* Half of all gates other than RG-2, 5, TG-1, 19, 21 & 35, at water line
2	25	RG-11	10D	10	16TDB	72TZE	72TZE	.....	10/38	10	4	Similar result L/D 15, RG-10, Pnl 5
3	25	RG-11	10C	11	16TDB	72TZE	72TZE	.....	10/38	11	4	Similar result L/D 15, RG-10, Pnl 6
4	5	*	*	10	16TDB	16TDB	72TZE	72TZE	7/38	16	16	* Half of RG-2, 5, TG-17, 19, 21 & 35 at water line
5	25	RG-10	10A	10	16TDB	72TZE	72TZE	.....	10/38	10	4	Similar result L/D 15, RG-10, Pnl 7
6	25	RG-10	10B	11	16TDB	72TZE	72TZE	.....	10/38	11	4	Similar result L/D 15, RG-10, Pnl 8
7	25	RG-10	10D	10	16TDB	72TLE	72TLE	.....	10/38	12	4	Similar result L/D 15, RG-10, Pnl 1
8	25	RG-10	10C	11	16TDB	72TLE	72TLE	.....	10/38	12	4	Similar result L/D 15, RG-10, Pnl 2
9	25	RG-11	11A	10	16TDB	88LTE	72TZE	.....	10/38	10	4	Similar result L/D 15, RG-10, Pnl 4
10	25	RG-11	11B	11	16TDB	88LTE	72TZE	.....	10/38	11	4	Similar result L/D 15, RG-10, Pnl 3
11	25	RG-10	12B	11	22TDB	22TDB	72TLE	72TLE	10/45	11*	11*	* Panel still in service 12/56, giving 90 % protection. 20% top coats worn off
12	26	TG-21	4	31	24TDB	24TDB	44TDB	44TDB	10/46	4	..	
13	20	TG-18, 19	*	10	25TDB	72TZE	72TZE	.....	7/38	14	..	* Entire gate
14	20	TG-16	*	10	25TDBS	72TZE	72TZE	.....	7/38	18†	..	* Entire gate, † In service 7/56
15	20	TG-17	*	10	25TDB	25TDBS	72TZE	72TZE	7/38	18†	..	* Entire gate, † In service 7/56
16	25	RG-10	3B	10	26TDB	26TDB	26TDB	.....	10/38	6	..	Similar result L/D 15, RG-10, Pnl 24
17	25	RG-10	3A	11	26TDB	26TDB	26TDB	.....	10/38	7	..	Similar result L/D 15, RG-10, Pnl 22
18	25	RG-11	17D	10	26TDB	26TDB	72TZE	.....	9/38	8	4	Similar result L/D 15, RG-9, Pnl 17
19	25	RG-11	17C	11	26TDB	26TDB	72TZE	.....	9/38	8	4	Similar result L/D 15, RG-9, Pnl 18
20	26	TG-21	5	31	29TDB	29TDB	29TDB	29TDB	10/46	7	..	
21	25	RG-10	13D	11	47TDA	47TDA	72TLE	72TLE	10/45	11*	10	* Pnl in service 12/56, giving 40% protection
Tung Oil + Resin Z												
22	15	RG-9	13	10	14TZA	72TZE	72TZE	.....	9/38	3	1	Similar Result L/D 25, RG-11, Pnl 18D
23	15	RG-9	14	11	14TZA	72TZE	72TZE	.....	9/38	6	1	Similar Result L/D 25, RG-11, Pnl 18C
24	15	RG-9	16	10	14TZA	72TZE	72TZE	.....	9/38	3	1	Similar Result L/D 25, RG-11, Pnl 18A
25	15	RG-9	15	11	14TZA	72TZE	72TZE	.....	9/38	6	1	Similar Result L/D 25, RG-11, Pnl 18B
26	15	RG-9	9	10	14TZA	72TLE	72TLE	.....	9/38	5	4	8:4 Result L/D 25, RG-11, Pnl 19D
27	15	RG-9	10	11	14TZA	72TLE	72TLE	.....	9/38	7	4	10:5 Result L/D 25, RG-11, Pnl 19C
28	15	RG-9	12	10	14TZA	88LTEBS	72TZE	.....	9/38	6	4	7:4 Result L/D 25, RG-11, Pnl 19A
29	15	RG-9	11	11	14TZA	88LTEBS	72TZE	.....	9/38	7	4	9:4 Result L/D 25, RG-11, Pnl 19B
30	15	RG-10	12	10	34TZA	33TZA	72TZE	.....	10/38	4	..	Similar Result L/D 25, RG-11, Pnl 18A
31	15	RG-10	9	11	34TZA	36TZA	72TZE	.....	10/38	4	2	Similar Result L/D 25, RG-11, Pnl 9A
32	15	RG-10	11	10	34TZA	72TZE	72TZE	.....	10/38	4	..	Similar Result L/D 25, RG-10, Pnl 8B
33	15	RG-10	10	11	34TZA	72TZE	72TZE	.....	10/38	4	..	Similar Result L/D 25, RG-10, Pnl 9B
34	25	RG-10	7B	11	35TZA	33TZA	72TZE	.....	10/38	8	7	Similar Result L/D 15, RG-10, Pnl 14
35	25	RG-10	7A	11	35TZA	72TZE	72TZE	.....	10/38	10	7	Similar Result L/D 15, RG-10, Pnl 13
36	15	RG-8	8	10	36TZA	33TZA	72TZE	.....	11/39	16*	..	* Pnl still in service 7/55
37	15	RG-8	7	11	36TZA	33TZA	72TZE	.....	11/39	16*	..	* Pnl still in service 7/55
38	15	RG-8	10A	10	36TZA	36TZA	36TZA	.....	11/39	7	..	
39	15	RG-8	9B	11	36TZA	36TZA	36TZA	.....	11/39	7	..	
40	15	RG-8	10B	10	36TZA	36TZA	33TZA	.....	11/39	7	..	
41	15	RG-8	9A	11	36TZA	36TZA	33TZA	.....	11/39	7	..	
42	15	RG-8	2	10	36TZA	36TZA	33TZA	72TZE	11/39	17	..	
43	15	RG-8	1	11	36TZA	36TZA	33TZA	72TZE	11/39	17	..	
44	15	RG-8	6	10	36TZA	36TZA	33TZA	72TZE	11/39	17*	..	* Pnl still in service 7/55
45	15	RG-8	5	11	36TZA	36TZA	33TZA	72TZE	11/39	17*	..	* Pnl still in service 7/55
46	15	RG-8	27	10	37TZA	37TZA	33TZA	72TZE	11/39	17	..	
47	15	RG-8	26	11	37TZA	37TZA	33TZA	72TZE	11/39	17	..	
48	15	RG-8	13	10	41TZA	41TZA	73TZE	.....	11/39	11	..	
49	15	RG-8	14	11	41TZA	41TZA	73TZE	.....	11/39	11	..	
Tung Oil + Resins Z and E												
50	25	RG-11	20D	10	9TZE	72TZE	72TZE	.....	9/38	9	5	6 Result L/D 15, RG-9, Pnl 5
51	25	RG-11	20C	11	9TZE	72TZE	72TZE	.....	9/38	14	5	15 Result L/D 15, RG-9, Pnl 6
52	5	*	*	10	9TZE	9TZE	72TZE	72TZE	7/38	16	..	* Water line of half of RG-2, 5 and TG-17, 19, 21 & 35
53	25	RG-11	20A	10	9TZE	72TZE	72TZE	.....	9/38	11	4	7 Result L/D 15, RG-9, Pnl 8
54	25	RG-11	20B	11	9TZE	72TZE	72TZE	.....	9/38	15	4	8 Result L/D 15, RG-9, Pnl 7
55	25	RG-11	21D	10	9TZE	72TLE	72TLE	.....	9/38	8	5	6 Result L/D 15, RG-9, Pnl 1
56	25	RG-11	21C	11	9TZE	72TLE	72TLE	.....	9/38	14	5	13 Result L/D 15, RG-9, Pnl 2
57	25	RG-11	21A	10	9TZE	88LTE	72TZE	.....	9/38	11	4	5 Result L/D 15, RG-9, Pnl 4
58	25	RG-11	21B	11	9TZE	88LTE	72TZE	.....	9/38	15	4	13 Result L/D 15, RG-9, Pnl 3
59	25	TG-1	9	11	12TZE	106TZE	12TZE	106TZE	4/42	10	..	
60	15	RG-10	1	10	58TZE	72TLE	72TLE	.....	9/38	10	6	Similar Result L/D 25, RG-10, Pnl 11A
61	15	RG-10	2	11	58TZE	72TLE	72TLE	.....	9/38	12	8	Similar Result L/D 25, RG-10, Pnl 11B
62	15	RG-9	5	10	58TZE	72TZE	72TZE	.....	9/38	12	8	10/6 Result L/D 25, RG-10, Pnl 10D
63	15	RG-10	6	11	58TZE	72TZE	72TZE	.....	9/38	12	8	Similar Result L/D 25, RG-10, Pnl 10C
64	15	RG-10	8	10	58TZE	72TZE	72TZE	.....	9/38	12	8	8/6 Result L/D 25, RG-10, Pnl 10A
65	15	RG-10	7	11	58TZE	72TZE	72TZE	.....	9/38	12	8	10/6 Result L/D 25, RG-10, Pnl 10B
66	15	RG-10	4	10	58TZE	88LTE	72TZE	.....	9/38	12	8	8/6 Result L/D 25, RG-10, Pnl 11A
67	15	RG-10	3	11	58TZE	88LTE	72TZE	.....	9/38	12	8	10/6 Result L/D 25, RG-10, Pnl 11B
68	15	RG-8	20	11	72TZEAS*	72TZE	72TZE	.....	11/39	..	17†	* Vehicle 60% solids, high viscosity
69	15	RG-8	21	11	72TZEAS*	72TZE	72TZE	.....	11/39	..	17†	† Still in service 7/55
70	4	RG-6	6	11	2TZEBS	72TZE	72TZE	.....	7/39	16	13	
71	5	TG-9	.....	41*	3TZEBS	3TZEBS	72TZE	72TZE	7/41	14	8	* Flame cleaned
72	26	TG-21	1 & 4	11	3TZEBS	3TZEBS	72TZE	72TZE	7/41	*	*	* Still giving good protection when removed in 1946
73	15	RG-2	*	11	4TZEBS	72TZE	72TZE	.....	7/40	..	15†	* Interior surfaces of gate † Still in service 7/55
74	16	TG-8	.....	11	4TZEBS	72TZE	72TZE	.....	7/40	10	8	

NOTE: All footnotes are explained in "Remarks" Column.

TABLE 3—Longevity of Paint Systems in Underwater Exposures (Continued)

Ref. No.	LOCATION			Surf. Prep.	SYSTEM (Coats)				Date Appl.	LIFE (Yrs.)		Remarks
	L/D No.	Gate No.	Panel No.		1 st	2 nd	3 rd	4 th		Prim.	Finish	
75	18	RG-2 & 3	.....	11	4TZEB	72TZEB	72TZEB	.....	7/40	..	16†	† Still in service 7/56
76	15	RG-3	.....	11	4TZEB	4TZEB	72TZEB	72TZEB	7/40	..	15†	* Interior surfaces of gate † Still in service 7/55
77	16	TG-11	1	11	4TZEB	4TZEB	72TZEB	72TZEB	7/39	15	11	
78	16	TG-13	2	11	4TZEB	4TZEB	72TZEB	72TZEB	7/39	13	11	
79	21	RG-3	.....	11	4TZEB	4TZEB	72TZEB	72TZEB	7/40	16	..	
80	4	RG-6	7	11	5TZEB	72TZEB	72TZEB	.....	7/39	16	13	
81	17	RG-1	1	11	6TZEB	73TZEB	73TZEB	.....	7/42	10	8	
82	17	RG-1	2	11	6TZEB	73TZEB	73TZEB	.....	7/42	8	6	
83	17	RG-2	.....	11	6TZEB	73TZEB	73TZEB	.....	7/42	10	8	
84	4	RG-5	.....	11	8TZEB	8TZEB	72TZEB	.....	7/39	17	3†	* 2nd coat 72TZEB appl. to rivet seams only. † New finish coat applied in 1942
85	15	RG-8	23	10	9TZEB	72TZEB	72TZEB	.....	11/39	17	..	
86	15	RG-8	22	10	9TZEB	72TZEB	72TZEB	.....	11/39	17	..	
87	5	.....	.....	10	9TZEB	72TZEB	72TZEB	.....	7/38	16	10	* 1/2 of all gates except RG-2, 5 and TG-17, 19, 31, and 33
88	24	TG-3	4	11	10TZEB	10aTZEB	10aTZEB	.....	10/43	9	4	
89	16	TG*	.....	11	11TZEB	11TZEB	72TZEB	72TZEB	7/39	9	7	* Gates 1, 2, 3, 4, 5, 10, 14, 15
90	18	RG-1	.....	11	11TZEB	11TZEB	72TZEB	72TZEB	7/40	..	16†	† Still in service 7/56
91	21	RG-1 & 2	.....	11	11TZEB	11TZEB	72TZEB	72TZEB	7/39	13	9	
92	26	TG-28	3	11	13TZEB	13TZEB	80TZEB	80TZEB	10/41	13	..	
93	26	TG-28	4	11	32TZEB	32TZEB	72TZEB	72TZEB	10/41	2	..	
94	4	RG-6	5	11	72TZEB	72TZEB	72TZEB	.....	7/39	16	7*	* Abraded spots touched-up 1947
95	4	RG-6	4	11	72TZEB	72TZEB	72TZEB	.....	7/39	16	5*	* Abraded spots touched-up 1947
96	15	RG-8	24	11	72TZEB	72TZEB	72TZEB	.....	11/39	..	16†	† Still in service 7/55
97	15	RG-10	18	10	72TZEB	72TZEB	72TZEB	.....	10/38	..	15	7 Result L/D 25, RG-11, Pnl 5B
98	16	TG-7	2	11	72TZEB	72TZEB	72TZEB	.....	7/40	10	8	15 Result L/D 15, RG-10, Pnl 17 7 Result L/D 25, RG-10, Pnl 5A 14/10 Result L/D 16, TG-9, Pnl 2
99	16	TG-12	1	11	72TZEB	72TZEB	72TZEB	72TZEB	7/39	15	12	
100	16	TG-12	2	11	72TZEB	72TZEB	72TZEB	72TZEB	7/39	13	11	
101	17	RG-3	.....	11	73TZEB	73TZEB	73TZEB	.....	7/42	8	6	
102	26	TG-30	4	11	82TZEB	82TZEB	82TZEB	82TZEB	10/41	11	..	
Tung Oil + Resin For G												
103	15	RG-8	15	11	42TFD	42TFD	73TZC	.....	11/39	7	..	
104	15	RG-8	16	10	42TFD	42TFD	73TZC	.....	11/39	7	..	
105	15	RG-8	11	10	43TGY	43TGY	73TZC	.....	11/39	10	..	
106	15	RG-8	12	10	43TGY	43TGY	73TZC	.....	11/39	10	..	
Tung—Linseed Oils + Resin E												
107	24	TG-3	2	11	10TLEB	10aTLEBS	10aTLEB	.....	10/43	9	4	
108	15	RG-10	15	10	34TLEX	36TLEX	72TLEB	.....	10/38	6	..	5 Result L/D 25, RG-10, Pnl 6A
109	15	RG-10	16	10	34TLEX	72TLEB	72TLEB	.....	10/38	6	..	Similar Result L/D 25, RG-10, Pnl 6B
110	25	TG-1	3	11	10TLEB	10aTLEBS	10aTLEB	.....	4/43	11	..	
111	25	RG-10	1	11	10TLEB*	10aTLEBS	10TLEB	10aTLEB	6/42	..	14†	* 1 pt. min. spts added/gal paint † Still in service 12/56—80% protection
112	25	RG-10	2	11	10TLEB*	10TLEB	10TLEB	10aTLEB	6/42	..	14†	* 1 pt. min. spts added/gal paint † Still in service 12/56—90% protection
113	25	RG-10	5B	11	10TLEB	10TLEB	10TLEB	10TLEB	10/45	..	11†	† Still in service 12/56—95% protection
114	25	RG-10	6B	11	10TLEB	10TLEB	10TLEB*	10TLEB*	10/45	..	11†	* 1/2 pt "Wood-Tox" added/gal paint † Still in service 12/56—95% protection
115	25	RG-10	8	11	10aTLEBS	10TLEB	72TLEB	72TLEB	6/42	14†	14*	* Top coats worn very thin † Still in service 12/56—65% protection
116	25	RG-10	5A	11	10TLEB	10TLEB	72TLEB	72TLEB	10/45	11†	11*	* Top coats worn very thin † Still in service 12/56—95% protection
117	25	RG-10	9	11	10TLEB	10aTLEB	72TLEB	72TLEB	6/42	14†	14*	* Top coats worn very thin, rust spots showing † Still in service 12/56—70% protection
118	25	RG-10	18	11	10TLEB	10aTLEBS	73TLEB	73TLEB	6/42	14†	12	† Still in service 12/56—75% protection
119	25	TG-1	10	11	10TLEB	10aTLEBS	73TLEB	73TLEB	4/43	9	7	
Tung—Castor Oils + Resin E												
120	8	TG-11	.....	11	49TCEM	49TCEMS	49TCEM	49TCEM*	10/45	10†	10†	* 5 coats 49TCEM. † Paint worn thin at water line. † 2 coats 72TZEB applied 1955. In service 7/55
Tung—Linseed Oils + Batu Resin												
121	26	TG-28	2	11	3TLNb	3TLNbS	72TLNb	72TLNb	10/41	2	..	
Linseed—Tung Oils + Resin E												
122	15	RG-10	19	11	15LTEA	77LTEA	77LTEA	.....	10/38	11	7	12/7 Result L/D 25, RG-10, Pnl 4
123	25	RG-11	14D	10	9LTEB	72TLEB	72TLEB	.....	9/38	12	..	10 Result L/D 15, RG-9, Pnl 29
124	25	RG-11	14C	11	9LTEB	72TLEB	72TLEB	.....	9/38	15	12	Similar Result L/D 15, RG-9, Pnl 30
125	25	RG-11	13D	10	9LTEB	72TLEB	72TLEB	.....	9/38	8	4	6 Result L/D 15, RG-9, Pnl 33
126	25	RG-11	13C	11	9LTEB	72TLEB	72TLEB	.....	9/38	14	5	Similar Result L/D 15, RG-9, Pnl 34
127	25	RG-11	13A	10	9LTEB	72TLEB	72TLEB	.....	9/38	8	5	12 Result L/D 15, RG-9, Pnl 36
128	25	RG-11	13B	11	9LTEB	72TLEB	72TLEB	.....	9/38	14	5	Similar Result L/D 15, RG-9, Pnl 35
129	25	RG-11	14A	10	9LTEB	88LTEB	72TLEB	.....	9/38	11	6	13 Result L/D 15, RG-9, Pnl 32
130	25	RG-11	14B	11	9LTEB	88LTEB	72TLEB	.....	9/38	14	6	16 Result L/D 15, RG-9, Pnl 31
Linseed—Castor—Oiticica Oils + Resin E												
131	26	TG-30	1	11	3LCOEB	3LCOEBS	72LCOEB	72LCOEB	10/41	9	..	
132	26	TG-30	2	11	3LCOEB*	3LCOEBS*	72LCOEB*	72LCOEB*	10/41	9	..	* Larger amount of drier added
133	26	TG-30	3B	11	3LCOEB	3LCOEBS	84LCOEB	84LCOEB	10/41	7	..	
134	26	TG-30	3A	11	3LCOEB	3LCOEBS	84LCOEB	84LCOEB	10/41	7	..	
135	24	TG-3	6	11	10LCOEB	10aLCOEBS	10aLCOEBS	.....	10/43	9	4	

NOTE: All Footnotes are explained in "Remarks" Column.



TABLE 3—Longevity of Paint Systems in Underwater Exposures (Continued)

Ref. No.	LOCATION			Surf. Prep.	SYSTEM (Coats)				Date Appl.	LIFE (Yrs.)		Remarks
	L/D No.	Gate No.	Panel No.		1 st	2 nd	3 rd	4 th		Prim.	Finish	
136	25	TG-1	4	11	10LCFEB	10aLCFEB	10LCFEB	10aLCFEB	4/43	8	..	† Still in service 12/56—95% protection † Still in service 12/56—95% protection * Top coats worn thin
137	25	TG-1	5	11	10LCFEB	10aLCFEB	10LCFEB	10aLCFEB	4/43	8	..	
138	25	TG-1	6	11	10LCOE	10aLCOE	10LCOE	10aLCOE	4/43	7	..	
139	25	RG-10	6A	11	10LCOE	10LCOE	10LCOE	10LCOE	10/45	..	11†	
140	25	RG-10	7A	11	10LCOE	10LCOE	10TLEB	10TLEB	10/45	11†	11*	
141	25	RG-10	7B	11	10LCOE	10LCOE	10TLEB*	10TLEB*	10/45	11†	11†	‡ Top coats worn thin * ¼ oz MIK added/zal paint
142	15	RG-7	F	11	91LCOEBIS	92XL1	92XL1	.....	10/41	6	..	† Still in service 12/56—90% protection
Linseed—Soya Oils + Resin K												
143	25	RG-11	19A	11	20LSBK	72TLEBS	72TLEB	72TLEB	10/45	11†	11*	† Still in service 12/56—75% protection * Some spots where top coats have separated from prime coat.
144	25	RG-10	3B	11	20LSBK	20LSBK	72TLEB	72TLEB	10/45	11†	11*	† Still in service 12/56—90% protection * Top coats worn thin
Dehydrated Castor Oil + Resins B and E												
145	25	TG-1	8	11	10CBB	10aCBB	10CBB	10aCBB	4/43	8	..	
146	25	TG-1	7	11	10CEB	10CEBS	10CEB	10aCEB	4/43	7	..	
Dehydrated Castor—Oiticica Oils + Resin A												
147	25	RG-10	17A	11	23COAA	23COAA	72TLEB	72TLEB	10/45	7	5	† Still in service 12/56—60% protection * Rust blisters over entire surface as if water had penetrated film. Considerable peeling of top coats.
148	25	RG-10	13A	11	46COAA	46COAAS	72TLEB	72TLEB	10/45	11†	11*	
Linseed Oils + Various Resins												
149	25	TG-1	1	11	10LEB	10aLEBS	10LEB	10aLEB	4/43	13†	13*	† Still in service 12/56—75% protection * Some abrasion at water line † Still in service 12/56—90% protection † Still in service 12/56—95% protection * About 20% Al finish coat worn off † Still in service 12/56—90% protection
150	25	TG-1	2	11	10LEB	10aLEBS	10LEB	10aLEB	4/43	13†	13*	
151	25	RG-10	3A	11	19LBKN <sub>e</sub>	19LBKN <sub>e</sub>	19LBKN <sub>e</sub>	81TDB	10/45	11†	11†	
152	25	RG-10	12AA	11	21LBKN <sub>e</sub>	21LBKN <sub>e</sub>	21LBKN <sub>e</sub>	72TLEB	10/45	11†	11*	
153	25	RG-10	12A	11	21LBKN <sub>e</sub>	21LBKN <sub>e</sub>	21LBKN <sub>e</sub>	81TDB	10/45	11†	11	
Soya Oil + Batu Resin												
154	26	TG-28	1	11	30SN <sub>b</sub> B	30SN <sub>b</sub> BS	72OSN <sub>b</sub> B	72OSN <sub>b</sub> B	10/41	2	..	
Linseed Oil—Unfortified												
155	8	†	.....	10	17Ln	17Ln	18Ln	.....	7/38	2	..	† Exterior underwater surfaces of RG's * Mixture of 17 and 18 Similar Result L/D 25, RG-10, Pnl 2A Similar Result L/D 25, RG-10, Pnl 2B 8/6 Result L/D 25, RG-11, Pnl 12A 9/6 Result L/D 25, RG-11, Pnl 12B
156	15	RG-10	24	10	17Ln	17Ln/18Ln*	18Ln	.....	10/38	4	..	
157	15	RG-10	23	11	17Ln	17Ln/18Ln	18Ln	.....	10/38	4	..	
158	15	RG-9	38	10	28Ln	72TZE	72TZE	.....	10/38	6	..	
159	15	RG-9	37	11	28Ln	72TZE	72TZE	.....	10/38	5	..	
Dispersion Resin Enamels												
160	2	†	.....	11	1XM1	1XM1S	71XM1	71XM1	12/40	7	2	† Stony Gates
161	26	TG-21	3	11	7XM1	7XM1S	72TZE	72TZE	7/41	6	..	
162	15	RG-7	B	11	7XM1	7XM1S	74XM1	74XM1	9/41	5	..	
163	26	TG-21	2	11	7XM1	7XM1S	76XM1	76XM1	7/41	3	..	
164	15	RG-7	D	11	7XM1	87TEDS	7XM1	7XM1	10/41	4	..	
165	15	RG-7	A	11	7XM1	87TEDS	74XM1	74XM1	9/41	9	..	
166	15	RG-7	G	11	7XM1	91LCOEBIS	85XM2	85XM2	10/41	13	..	
167	15	RG-7	E	11	7XM1	91LCOEBIS	7XM1	7XM1	10/41	5	..	
168	26	TG-21	8	31	31XM1	31XM1	83TCEM	83TCEM	10/46	2	..	
169	15	RG-7	H	11	48XL2	91LCOEBIS	86XL3	86XL3	10/41	8	..	
170	15	RG-7	C	11	86XL3	91LCOEBIS	86XL3	86XL3	10/41	6	..	† Bakelite formulation † Bakelite formulation
171	15	RG-8	3	11	112†	112†	114†	114†	11/39	3	..	
172	15	RG-8	4	11	112†	112†	114†	114†	11/39	3	..	
Alkyd Resin Enamels												
173	25	RG-11	17A	10	27	27	72TZE	.....	9/38	4	..	8 Result L/D 15, RG-9, Pnl 20 13 Result L/D 15, RG-9, Pnl 19
174	25	RG-11	17B	11	27	27	72TZE	.....	9/38	8	4	
Rubber												
175	15	RG-10	20	10	56	56	56	56†	10/38	3	3	† 5 coats. Similar Result L/D 25, RG-10 Pnl 1
Cumar Resin Enamels												
176	26	TG-21	6	31	45XN <sub>e</sub>	45XN <sub>e</sub>	45XN <sub>e</sub>	45XN <sub>e</sub>	10/46	2	..	
177	26	TG-21	7	31	30XN <sub>e</sub>	30XN <sub>e</sub>	30XN <sub>e</sub>	30XN <sub>e</sub>	10/46	6	..	

NOTE: All footnotes are explained in "Remarks" Column.

TABLE 3—Longevity of Paint Systems in Underwater Exposures (Continued)

Ref. No.	LOCATION			Surf. Prep.	SYSTEM (Coats)				Date Appl.	LIFE (Yrs.)		Remarks
	L/D No.	Gate No.	Panel No.		1 st	2 nd	3 rd	4 th		Prim.	Finish	
Vinyl Enamels												
18	24	TG-3	5	11	38XVym2	39XVy1	78XVy2	‡	10/43	6	*	‡ Total thickness of film 0.002" * Pnl removed 7/55. Below water areas giving 50% protection. Bottom downstream face worn to base metal
19	24	TG-3	1	11	40XVym1	39XVy1	78XVy2	‡	10/43	5	*	‡ Same as Pnl 5 * 40% protect fon
10	24	TG-3	3	10	40XVym1	39XVy1	78XVy2	‡	10/43	5	*	‡ Same as Pnl 5 * 35% protection
11	26	TG-21	2	31	54V	54V	89V	89V‡	10/46	5	..	‡ Fifth coat 89V
12	26	TG-21	3	31	54V	54V	89V	89V‡	10/46	5	..	‡ On 12/56, lower downstream half worn to bare metal. Above-water portion giving 70% protection
13	26	TG-21	4	31	57XVx	52XVa	75XVy2	.....	10/46	8	†	
Tars												
14	4	RG-6	.....	30	53	53	.....	.....	7/39	2	..	† In service 7/55. Gate continuously under water
15	15	RG-1	.....	10	55	90	.....	.....	7/39	16†	..	† In service 7/55. ‡ Interior surfaces.
16	20	RG-3	‡	20	59	59	.....	.....	11/42	14†	..	Same as RG-3
17	20	RG-2	‡	20	60	60	.....	.....	11/42	14†	..	
18	20	TG-2	.....	10	55	55	55	55	12/41	1	..	
Metallized Coatings												
19	8	.....	17 ‡	*	0.012" Zinc	.....	.....	.....	7/38	2	..	‡ Water line areas. *Grit blast
10	15	RG-8	17	10	0.010" Zinc	.....	.....	.....	11/39	10	..	
11	15	RG-8	18	10	0.008" Zinc + 0.008" Aluminum	.....	.....	.....	11/39	16†	..	† Still in service 7/55
12	15	RG-8	19	10	0.016" Aluminum	.....	.....	.....	11/39	16†	..	† Still in service 7/55

NOTE: All footnotes are explained in "Remarks" Column.

### (a) Metal Preparation

#### (1) Sandblasting and Cleaning

Proper preparation of metal surfaces prior to paint application is essential for varnish or lacquer-type paints applied to surfaces to be subjected for prolonged periods of time (three weeks or more) to underwater exposure or conditions of high humidity. Sandblasting to base metal and elimination of surface contaminants such as grease, millscale, and the like is necessary to insure adhesion between the paint and metal. (See Ref. Nos. 11 and 12, 70 and 71 in Table 3.)

#### (2) Chemical Inhibitors

Contrary to the previous findings, the use of properly formulated and applied phosphoric acid inhibitive wash solutions on sandblasted surfaces immediately prior to application of paint may not increase longevity to the extent previously believed. Where the paint systems used are of the high-grade types which are inherently long-lived, use of the inhibitor may not add appreciably to longevity. At most it may add about two years when an oleoresinous primer is used. Approximately equal results are obtainable by the use of a vinyl wash primer similar to Formula 57. For typical examples see Ref. Nos. 22 to 27, 50 to 58, 123 to 130.

### (b) Sand Reinforcement

The sand reinforcement indicated in Table 3 by the final letter "S" is done by applying a heavy coat of primer and while this is wet blowing fine sand (passing 30-mesh but retained on a 50-mesh screen) onto the coating with an air pressure of two to four pounds per square inch until the coating cannot hold any more. When the sand-reinforced coating is dry, loose sand is brushed off, and subsequent finish coats of paint applied. By this means, an amount of paint normally sufficient to create a five to seven mil thickness results in a film having an actual thickness of 12 to 14 mils. It is essential, when using sand

reinforcement, that the vehicle used stay wet enough to permit embedment of the sand, and be able to form membranes sufficiently strong to hold the embedded grains under severe abrasion. There is a division of opinion as to whether the reinforcement should be in the first or second coat, followed by the seal coats.

Contrary to the previous findings, it now appears that use of sand reinforcement may not increase longevity to the extent previously believed. However, the use of the reinforcement does improve intercoat adhesion between coatings where the undercoat dries very hard and shiny, and will increase longevity of top coats which may be somewhat brittle. Incidentally, one theory for the increased longevity of such top coatings is that the surface area of the membranes, by virtue of encased sand grains, is substantially larger than that of the underlying metal and hence, in cross-section is subjected to considerably less stress by expansion and contraction of the underlying metal than would be a smooth paint film of equal thickness. For typical comparisons between sand-reinforced and non-reinforced coatings, see Ref. Nos. 13, 14, 15, 36 to 47, 77, 78, 82, 83, 98, 99, 100.

### (c) Multiple Paint Coats

The use of a four-coat system will normally increase the life of the coating at least three years over that of a three coat system. (See Ref. Nos. 3, 4; 98, 100.)

### (d) Inhibitive Primers

Panels on Tainter Gates 7, 9, 12 in comparison with those on the other Tainter Gates at Dam 16 definitely show that the use of inhibitive pigments in prime coats is unnecessary to ensure longevity with high grade oleophenolic-resin vehicles such as TZE. (See Ref. Nos. 74, 77, 78, 89, and 98 to 100.)

### (e) Intercoat Adhesion

Adhesion between successive coats of paints containing aluminum as all or

part of the pigment is excellent. This is not true of intercoat adhesion between prime coats of red-lead-varnish paints and succeeding top coats, whether of the same or differently pigmented paints. In such cases, intercoat adhesion can be improved by using sand reinforcement in the primer (as noted in conclusion "b" above) and/or using a powerful solvent such as methyl-isobutyl-ketone or methyl-ethyl-ketone at the rate of 4 oz per gallon of paint in the succeeding paint coat.

Similar troubles sometimes are encountered in the iron-oxide zinc-chromate pigmented varnish paint primers. The cause is usually the highly polished hard surface formed by the red lead or iron-oxide varnish films. For typical examples see Ref. Nos. 2, 3, 5 to 10, 18, 19, 50, 51, 53 to 57.

### (f) Vehicles

#### (1) Phenolic Resins

Among the oleoresinous vehicles, paints formulated with vehicles of 100 percent tung oil reinforced with either BR 1329, BR 254, or BR 4036 are superior to those formulated with vehicles of combinations of tung with other oils or those of other oils, reinforced with phenolic resins (Compare Ref. Nos. 1 to 106 with 107 to 153). There appears to be little difference in durability of paints formulated with vehicles of either the 25 or 33-gallon length, although both are superior to those of longer length such as 50 gallon. (See Ref. Nos. 103 to 106.)

#### (2) Natural Oils

Because of their short life, vehicles of unreinforced natural oils are unsuitable for paints in underwater exposures. This is strikingly verified by comparison of the life of the unfortified linseed oil paint systems (Ref. Nos. 155 to 159) with those of the fortified linseed systems (Ref. Nos. 149 to 153).

### (3) Natural Resins

Vehicles of natural oils reinforced with natural resins have considerably lower life in underwater exposure than those fortified with phenolic resins. (See Ref. Nos. 121, 154, 176, 177.)

### (4) Dispersion Resins

Paint systems of dispersion resin vehicles normally are unsuitable for underwater use because they form porous coatings resulting in pinpoint rusting. However, they have excellent adhesion to metal and excellent intercoat adhesion and form a hard tenacious coat. As may be noted from panel G, Roller Gate 7 at Dam 15 (Ref. No. 166), the porosity may be readily corrected by use of an oleoresinous intercoat to seal the pores and by use of sand-reinforcement to obtain longevities almost equal to those of the tung-oil phenolic resin varnishes. The dispersion resins have the advantage of rapid drying, permitting the application of subsequent coats in quick succession. Because they dry by evaporation instead of by polymerization, they are readily adaptable for use in cold weather. However, on the basis of other tests, not reported in this article, it appears that the vinyl paints have all of the advantages and none of the disadvantages of the dispersion resins. (Ref. Nos. 160 to 172.)

### (5) Alkyds

Red-lead alkyds have lower life in underwater exposures than the red-lead phenolic paints (Ref. Nos. 173, 174). However, the linseed-phenolic-alkyd-cummar (LBKNC—Ref. No. 151, 152) and linseed-soya-phenolic-alkyd (LSAK—Ref. No. 143) show promise of equalling the effectiveness of the phenolics.

### (6) Vinyls

Vinyls have all the virtues and few of the defects of the oleoresinous paints. When applied to a minimum thickness of 5 mils, they have a life at least equal to that of the tung-oil phenolic paints. They have the additional virtue of extremely rapid drying permitting the application of paint coats to be continuous. Furthermore, in the event the coating is marred by scratches at anytime during its existence, repairs will bond to underlying coats by virtue of the solvents dissolving a sufficient portion of the undercoat to permit the coating to form an integral whole. This is not true of any coatings which form by polymerization. However, as may be seen from Panels 1, 2, and 3, Tainter Gate 21, Dam 26 (Ref. Nos. 181 to 183), vinyls designed for use with the wash primer system appear to have greater life than those which do not use it because of the poor adhesion between metal and the straight vinyl-acetate or vinyl-chloride films.

As may be noted also, the thinner film of panel 2 (Ref. No. 181) had a shorter life than the somewhat thicker film of panel 3 (Ref. No. 182), although it is suspected that neither film had the desired 5 mil thickness.

### (g) Coal Tar and Asphalts

As may be noted from Roller Gate 6, Dam 4 (Ref. No. 184), asphalt coatings are unsuitable for underwater exposures. However, hot applied coal tar coatings give excellent service to surfaces continuously underwater as may be noted from Roller Gate 1, Dam 15 (Ref. No. 185). Cold applied coal tar coatings are unsuitable for underwater surfaces subject to abrasion, but, as may be noted from Roller Gates 2 and 3 at Dam 20 (Ref. Nos. 186 and 187), they provide excellent service where abrasion and/or ultra-violet light are absent.

### (h) Metalized Surfaces

Hot spray metal coatings give excellent protection when properly applied to a thickness of .016 inch or greater. Such thickness appears to be necessary to overcome the inherent porosity of the coating. Recent tests, not listed in Table 3, indicate that the porosity can be overcome by coating the surface with the vinyl wash primer and a top coat of vinyl, or by burnishing the surface. The vinyl coating appears preferable. (Ref. Nos. 189 to 192.) The few tests listed do not appear to justify further conclusions.

### (i) Thickness of Paint Films

All other things being equal, longevity of paint films appears to be a function of thickness. Whether this has an upper limit (point of diminishing return) has yet to be determined by experiment. As indicated in (b) and (c) above, use of multiple coats to increase thickness up to at least 14 mils is well worth the expenditure of labor and materials for the extra coats when balanced against the costs of more frequent repaintings.

It is regretted that relatively infrequent records were made of film thicknesses of the various test panels. In general, it may be stated that for oleoresinous paints, average film thicknesses for the systems were three coat, 4 to 6 mils; four coat, 5 to 8 mils, and sand-reinforcement added about 5 to 7 mils to these thicknesses. On lacquer-type coatings, thicknesses varied from 2 to 5 mils.

### (j) Aluminum

As may be seen in comparing systems using pigmentation Formulae 72 vs 73 and Formulae 3 and 4 vs 6, not less than two pounds of aluminum pigment paste should be used per gallon of oleoresinous vehicle for maximum longevity. For typical examples see Ref. 71 to 79, 81 to 83, and 116 to 119.

### (k) Rubber

Formula 56 was found completely unsuitable for underwater exposure because of poor adhesion to metal.

The tests covered by Table 3 demonstrate the thesis set forth at the beginning of this paper, namely that there is a need for a science of paints and painting, and that to properly protect metal surfaces from corrosion it is

necessary to know the properties and characteristics of the materials to be employed for such protection. These tests make clear that particularly in underwater exposures, there is a wide range in longevity of various paint systems and that longevity is affected by a variety of other factors in addition to the materials used for protection. The field is wide and is only now being really explored.

The materials listed in Table 3 are not the only ones being tested by the Corps of Engineers. Subsequent to these tests, extensive tests have been made on vinyls and the other newer compounds such as the chlorinated rubbers, epons, polyethylenes, and silicones, as well as the older compounds such as the coal tars, bitumens, and natural and reinforced drying oils. In addition to the tests in fresh waters, coating systems also are being tested in rural, industrial, salt water and other exposures. Gradually, as data accumulates and is published, it is believed that it will be possible to accurately predict the behavior and characteristics of various coatings in various exposures. When that time arrives, painting will really have become a branch of the engineering sciences.

It is unfortunate that there are little available published current data concerning coatings for underwater exposure in fresh waters. Some of the publications known to the writer are listed in the bibliography section.

It is hoped that as test data accumulates, it will be promptly published, even if only as preliminary reports, to bridge the present dearth of factual information.

### Acknowledgments

By letter of Office, Chief of Engineers, Corps of Engineers, U. S. Army, the writer was authorized to use the listed data of the Corps of Engineers in preparation of this paper. However, it is to be distinctly understood that any conclusions or opinions expressed in this article are those of the writer and may or may not represent the opinions and policy of the Corps of Engineers.

All photographs used in this paper were made by the Corps of Engineers, and permission to use them in this publication is gratefully acknowledged.

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3. Manual on Painting (issued by the Bureau of Reclamation, Interior Department, Washington, D. C.).
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  - (a) Steel Structures Painting Manual
  - (b) Surface Preparation Specifications
  - (c) Pretreatment Specifications
  - (d) Paint Application Specifications
  - (e) Paint Specifications
  - (f) Paint Systems Specifications

Any discussions of this article not published above  
will appear in the December, 1958 issue



# An Eddy Current Gauge For Measuring Aluminum Corrosion\*

By W. E. RUTHER\*

## Introduction

THE MEASUREMENT of aqueous aluminum corrosion at high temperature is complicated by the partial retention of the corrosion product as a resistant coating. Since a varying fraction of the total corrosion product is retained, estimates of amount of corrosion based directly on weight gains are likely to be in serious error.

To establish a point on the corrosion versus time curve, the coating must be separated from the metal and the metal loss computed. Each sample can thus supply only one point. Unfortunately, different samples tend to produce parallel rather than identical curves of corrosion versus time. As the initial differences are relatively large and the subsequent corrosion rate relatively small, a great uncertainty in the plotted corrosion rate results from this simple method.

A number of recent investigators<sup>1,2,3,4</sup> have used nondestructive electrical resistance methods for measuring corrosion. These methods generally employ a relatively long, thin foil or wire specimen to achieve sensitivity. Since the corrosion testing described here was to be accomplished in rapidly flowing water (~20 feet per second) a specimen of this sort was unsuitable.

Two eddy current systems for measuring the corrosion of 1100 aluminum rod and sheet have been developed by this laboratory. One of these systems already has been reported<sup>5</sup>. A modification of the other system, described in this article, permitted the use of a sample suitable for dynamic corrosion testing.

## Experimental Technique

The impedance of a coil is dependent upon the shape and amount of conducting metal placed within it. The presence of a nonconducting coating on the metal does not affect the impedance measurement. Since the resistance of the metal is important, care must be taken to eliminate any extraneous heat treatment effects that might occur from testing at high temperatures. Calibration should include surface roughening effects.

The corrosion specimens were made of M388 aluminum alloy (1 percent nickel added to 1100 aluminum). The metal was pretreated for 10 days at the test temperature of 260°C. This was shown to be adequate to prevent serious subsequent thermal resistance changes. A sample  $2 \times \frac{1}{2} \times \frac{1}{8}$  inches was used with the long edges milled to fit the curvature of a 0.090 inch artificial sapphire rod. The sapphire rod was used in the dynamic test channels to provide electrical insulation between the aluminum specimens and the stainless

steel channel. The same size sapphire rod was used to accurately position the specimen within the measuring inductor as shown in Figure 1.

Surrounding the sample was a close fitting coil of 800 turns of No. 36 enameled copper wire. A magnetic return path made from ferrite eliminated the effects of the surroundings on the measurement. The specimen was arranged so as to slide in and out of the coil on the sapphire ways.

A block diagram of the complete apparatus is shown in Figure 2. A stable 100 kilocycle per second quartz crystal oscillator was used to control the measuring frequency. Multivibrator count down circuits reduced the frequency to 4 KC.

A circuit diagram of the special oscillator is shown in Figure 3. Since a

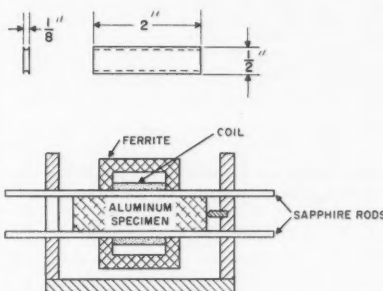


Figure 1—Top drawing shows dynamic corrosion specimen. At bottom is shown a section through sensing coil.

## Abstract

The construction of a device for the non-destructive measurement of aluminum corrosion is described. An alternating current bridge measurement of the impedance of a coil containing a corroded aluminum specimen may be directly converted to average metal loss per sq cm. No contacts are required on the specimen and the AC measurement is quickly and easily performed.

A dynamic aqueous corrosion test at 260°C is described in which this method was used.

2.4.2

resonant bridge circuit was used, oscillator frequency stability was very important. With the bridge components used it was estimated that a frequency stability of better than one part per million was required to permit precise setting of the bridge variable condenser to the nearest micromicrofarad. Quartz crystals are now available for direct frequency control at 4 KC and would permit a considerable simplification of the oscillator circuitry.

The circuit diagram for the measuring bridge is shown in Figure 4. The

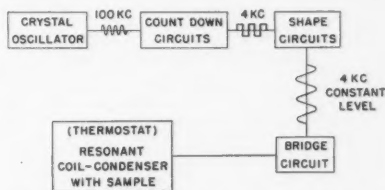


Figure 2—Block diagram of eddy current thickness gauge.

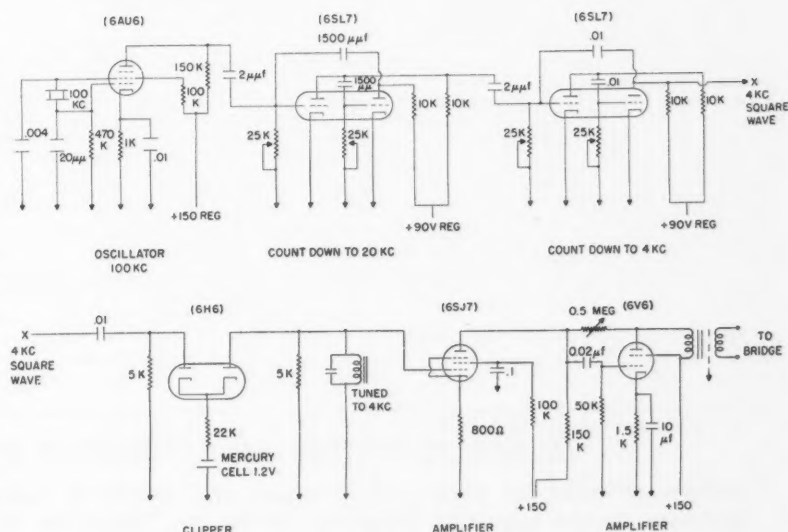


Figure 3—Bridge oscillator.

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\* Argonne National Laboratory, Lemont, Illinois.

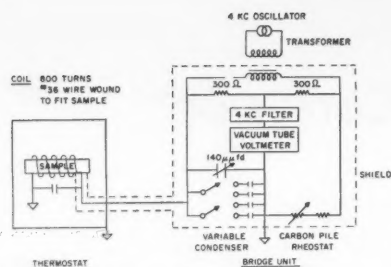


Figure 4—Schematic of eddy current thickness gauge.

coil containing the sample was tuned to resonance at 4 KC using the calibrated variable air condenser, with additional calibrated decade condensers being provided to extend the range of the instrument. The rheostat was not calibrated since it was merely adjusted for the best null. The total voltage supplied was one volt.

The vacuum tube voltmeter used was a Ballantine Model 310A with a Model 220 Decade Amplifier. The null was found on the 1–10  $\mu$  volt scale.

The temperature of the sample, coil, and large padder condenser (about 0.35  $\mu$  F) was accurately maintained. These components were mounted in a small closed chamber surrounded on five sides by a constant temperature water bath ( $\pm 0.01$  C). Air also was passed through a heat exchange unit in the water bath and blown into the thermostat chamber. The time for thermal equilibrium was reduced by storing the samples to be measured in the thermostat for about 15 minutes prior to measurement. The actual time for an individual read-

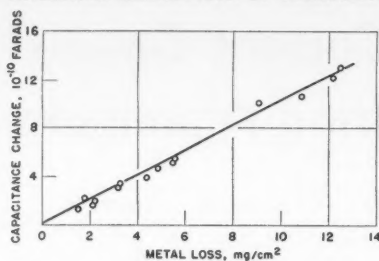


Figure 5—Calibration curve for eddy current thickness gauge. Data were obtained by defilming M388 samples corroded at 260 C in H<sub>2</sub>O.

ing was about 3 minutes. The electronic circuitry was checked periodically by remeasuring an uncorroded sample.

#### Corrosion Test

A dynamic corrosion test in 260 C distilled water with flow velocities of 2 and 22 feet per second was performed. A calibration curve for this test was obtained by chemically defilming samples actually used in the test (Figure 5). Deviations from a perfect linear relationship were as likely to be defilming errors as inaccuracies in the gauge readings. The fortuitous numerical correspondence between the change in capacitance in  $10^{-10}$  Farads and the metal loss in mg per cm<sup>2</sup> made converting from one unit to another especially simple. Since the bridge could be set to  $\pm 1$   $\mu$ F, the sensitivity of the method approached 1 mg/dm<sup>2</sup> for this particular alloy.

The results of a dynamic corrosion test are shown in Figure 6. Through the use of the calibration plot (Figure

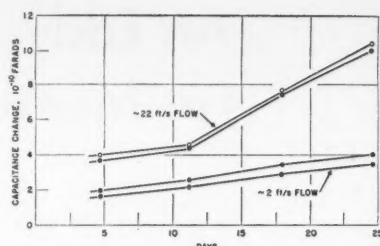


Figure 6—Raw data obtained for four M388 samples corroded at 260 C in distilled water.

4) these electrical data were used to calculate the corrosion rates. For example, at the flow of 2 feet/second, the uniform corrosion rate corresponding to the linear portion of Figure 6 was 12 mg/dm<sup>2</sup>/day.

The present instrument represents a compromise between rugged, easy to handle samples and high sensitivity. This gauge is being used as a standard tool in conjunction with the dynamic corrosion testing of aluminum at Argonne National Laboratory.

#### Acknowledgment

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Any discussions of this article not published above will appear in the December, 1958 issue

### TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of *Corrosion*. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

# Observations on Corrosion Resistance Of High Strength Stainless Steels for Aircraft\*

By JOHN HALBIG and O. B. ELLIS

## Introduction

DURING THE past ten years a variety of corrosion data have been developed on the precipitation hardening stainless steels. This paper discusses the findings of some of the workers conducting such investigations. While most of the corrosion information reported here pertains to three Armco proprietary alloys, comparative performances of other stainless steels also are shown. These latter steels include the regular hardenable chromium grades and to some extent their modifications.

## Need For High Strength Steels

Heat generated by air friction in supersonic flight reduces the useful strength of airframe materials. As a result there is a demand for aircraft structural materials with high strength both at room and at elevated temperatures. These materials must be readily available in quantity and must be capable of being easily formed and yet develop the desired properties.

An ideal material for aircraft structures should have the following properties:

1. High strength at elevated temperatures.
2. High modulus of elasticity.
3. Low density.
4. High thermal conductivity.
5. Low strategic alloy content.
6. Resistance to thermal shock.
7. Resistance to thermal cycling.
8. Resistance to fatigue.
9. Resistance to corrosion.
10. Resistance to nuclear radiation.

It is apparent that all these properties are not combined in any one material. However, steels with high strength at elevated temperatures, particularly under sustained and cyclic loading conditions, have been found to be useful.

Nekervis, Lund and Hall<sup>1</sup> in a recent survey of the status of high strength steels for the aircraft industry report that six major classes of steels show promise for application in aircraft skins. These steels also can be used for other shapes such as bar stock, forgings, and castings. They are:

1. The hot-work tool steels such as Peerless 56, Potomac M and Vasco Jet 1000.
2. The martensitic stainless steels such as Types 422 and 422 Modified.
3. The low-alloy hardenable steels such as the AISI 4300 series and Timken 17-22A.
4. The precipitation hardening semi-austenitic stainless steels such as PH 15-7 Mo, 17-7 PH, AM 350, and 17-4 PH.

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O. B. ELLIS is senior research engineer with Armco Steel Corporation, Middletown, Ohio. He has a BS in chemistry, 1922 and an MS in physics, 1924 from University of Louisville, Ky. Mr. Ellis has been in the company's research laboratories since 1932 where he is engaged in corrosion research.

5. The cold-rolled austenitic stainless steels such as those of the AISI 200 and 300 series.
6. The precipitation hardenable austenitic stainless steels such as HNM and A-286.

Structural parts of the F-86, the F-100, F-102, F-104, F-105, B-52 and B-58 have been made of 17-7 PH. This material also has been specified for welded, lightweight high pressure missile tanks. Because of ease of machining and simplicity of heat treatment, 17-4 PH was adopted where massive forgings and fittings with high strength were needed for aircraft and missile parts. It is interesting to note Nekervis, Lund and Hall remark that the precipitation hardening semi-austenitic type stainless steel is rapidly becoming the work horse of the industry. This is because this type of steel combines the higher strength obtainable by martensitic transformation with "stainlessness" and ease of fabrication.

## Abstract

Stainless steels of the precipitation hardening type are used extensively in airframe components. In this paper, compositions and properties of several of these alloys are described. The corrosion performances of the Armco 17-4 PH and 17-7 PH precipitation hardening alloys are compared with those of other hardenable stainless steels. The results of accelerated corrosion tests with these materials in both bar and sheet form are reported for a number of acids of varying concentrations and temperatures. Data also are presented for the new precipitation hardening stainless alloy PH 15-7 Mo.

Properties needed in materials used for aircraft structures are itemized. Variables affecting corrosion resistance of precipitation hardening stainless steels are discussed briefly. Other topics covered include resistance to high temperature-high purity water, effects of nitriding, atmospheric corrosion resistance, resistance to sea water, galvanic corrosion, stress cracking, and brazing and welding. 6.2.5

## Materials To Be Considered

Of the various high strength steels mentioned thus far for airframe usage there is considerable interest in comparative corrosion performance of two: the martensitic stainless steels and the semi-austenitic precipitation hardening stainless steels. These will be compared, with particular emphasis on 17-4 PH, 17-7 PH and PH 15-7 Mo.

## Martensitic Stainless Steels

The martensitic stainless steels are a family of steels based on the iron-chromium-carbon system. High strength is developed by hardening at 1800 to 1850 F followed by stress relieving or tempering within the range of 600 to 1300 F.

The compositions most useful for aircraft skin surfaces are Type 422 and several modifications thereof. Type 422, which has 12 percent chromium and 0.20 to 0.35 percent carbon, is itself a lower carbon modification of Type 420. Type 422 also contains small quantities of molybdenum, vanadium and tungsten. The production of 420, 422 and modified 422 alloys in sheet form is a relatively new undertaking.

When hardened, these alloys are related in corrosion resistance to hardened Type 410. Because of their high carbon content their corrosion resistance is generally inferior to hardened Type 410. Hardened Type 431 has even better corrosion resistance than 410 and its performance is indicative of the best to be expected from this group of alloys.

## Precipitation Hardening Stainless Steels

There are a number of different kinds of precipitation hardening stainless

TABLE 1—Nominal Analyses for Three Precipitation Hardening Stainless Steels

SPECIMEN	C	Cr	Ni	Mo	Al	Cu	Cb-Ta
17-4 PH.....	0.04	16.20	4.00	.....	.....	3.50	0.25
17-7 PH.....	0.07	17.00	7.00	.....	1.15	.....	.....
PH 15-7 Mo.....	0.07	15.00	7.00	2.25	1.15	.....	.....



TABLE 2—Corrosion Rates in Mills Per Year<sup>a</sup> Based on Laboratory Tests\*

SPECIMEN	Form	Treatment	H <sub>2</sub> SO <sub>4</sub> At 35C			H <sub>2</sub> SO <sub>4</sub> At 80C		HCl At 35C	
			1%	2%	5%	1%	2%	0.5%	1%
Type 431	Bar	H&SR	523	1190(4)	1600(2)	1800(1)	3500	501	1800(2)
Type 431	Bar	H&SR	820	2000(4)	2300(2)	1600(1)	12000(1)	780	2200(2)
17-4 PH	Bar	H875	0.0	0.0	1.7	1.1	10.8	1.0	37
17-4 PH	Bar	H925	0.0	0.0	1.4	1.3	7.4	1.7	35
17-4 PH	Bar	H1025	0.0	0.0	0.7	0.0	10.0	2.1	206
17-4 PH	Bar	H1075	0.0	0.0	11.3	0.9	12.5	2.6	518
17-4 PH	Bar	H1150	1.2	0.5	1.0	3.0	23.7	45.0	729
17-4 PH	Bar	H925	0.0	0.0	7.6	1.4	10.3	1.8	32
17-4 PH	Bar	H1025	1.0	0.9	11.6	2.8	6.8	1.6	140
17-4 PH	Bar	H1150	0.3	0.7	12.6	0.7	12.5	1.5	675
17-4 PH	Bar	H925	0.3	0.7	3.2	0.7	5.2	3.3	38
17-4 PH	Bar	H1025	0.0	0.0	7.7	0.7	9.9	1.8	177
17-4 PH	Bar	H1150	0.0	0.0	13.3	0.7	14.0	2.1	546
17-7 PH	Bar	TH850	540	298	1190	1320(3)	2420(3)	64	262
17-7 PH	Bar	TH950	283	700(3)	2110(2)	1360(3)	2490(3)	202	482
17-7 PH	Bar	TH1050	4.1	53	283	284	706	111	1050
17-7 PH	Bar	TH1150	4.9	7.7	155	123	441	26	823
17-7 PH	Bar	RH950	39.9	134	554	629(3)	169(3)	33	153
17-7 PH	Sheet	TH850	0.5	0.8	830(2)	756(3)	1860(1)	16	95(1,b)
17-7 PH	Sheet	TH950	133.0	368	1590(1)	819(2)	1890(1)	205	476(1,b)
17-7 PH	Sheet	TH1050	0.6	1.4	226	258	603(3)	100	768(1,b)
17-7 PH	Sheet	TH1100	0.4	0.6	46	27.7	415	84	674(3)
17-7 PH	Sheet	TH1150	0.6	0.8	195	32.4	500	35	518
17-7 PH	Sheet	RH950	0.3	0.9	143	265	749(2)	6.6	400(2)
17-7 PH	Sheet	RH1050	7.8	60	783(3)	409	1030(2)	173	795(2)
17-7 PH	Sheet	TH850	0.4	0.2	467	580(3)	1390(1)	9	47.6
17-7 PH	Sheet	TH950	33	116	853(2)	513(3)	1480(1)	11	183.3
17-7 PH	Sheet	TH1050	0.4	0.4	22	1.8	145	31	622(3)
17-7 PH	Sheet	TH1100	0.2	0.5	16	1.6	36	21	533(3)
17-7 PH	Sheet	TH1150	0.2	0.6	68	0.8	171	21	494(3)
17-7 PH	Sheet	RH950	0.0	0.5	126	329	839(2)	1.4	184
PH15-7 Mo	Sheet	TH950	0.0	26.7	260	760(2)	1400(1)	5.2	64
PH15-7 Mo	Sheet	TH1050	273	78	453	560(3)	1300(2)	31	280
PH15-7 Mo	Sheet	RH950	0.5	0.7	482	690(2)	1440(1)	0.3	152
Type 304	Bar	Ann.	28	57	240	350	480	33	240
Type 304	Sheet	Ann.	0.4	0.4	1.2	1.2	67	0.4	20.8
Type 304	Sheet	Ann.	0.4	2.3	14.3	43.3	62	13.8	13.9

a Rates were determined by total immersion for five 48-hour periods. Specimens were activated last three periods except in boiling 65 percent nitric acid for all grades and also for Type 304 bar in boiling sodium hydroxide. For Type 304 bar passive periods were not averaged. In most cases, where rates of replicates varied, highest is given. Other exceptions to all of foregoing are marked.

b Cracked during test.

( ) Rate is average for number of periods indicated by italic type in parenthesis.

\*See References 10, 11 and 12.

steels. The literature contains several references<sup>1,2,3</sup> regarding distinct groupings. Carruthers<sup>4</sup> points out that precipitation hardening can be accomplished in alloys in each of the three conventional categories of stainless steels (i.e., the ferritic, the martensitic, and the austenitic stainless steels).

As indicated in Table 1, 17-4 PH contains about 16 percent chromium, 4 percent nickel and 3.5 percent copper. This alloy is supplied in the form of plates, bar, wire, rods and billets. Many foundries have been licensed to produce castings of this material.

17-7 PH contain 17 percent chromium, 7 percent nickel and 1 percent aluminum. 17-7 PH is produced in the form of sheet, strip, plate, bar, wire, rods and billets.

In the past ten years improvements in processing and changes in heat treating procedures have brought higher strength at room and elevated temperatures. This has enhanced appreciably the value of these alloys as engineering materials.

In 1957 a new precipitation hardening stainless steel, PH 15-7 Mo, became available. This new alloy contains 15 percent chromium, 7 percent nickel, about 1 percent aluminum and 2 percent molybdenum. Guaranteed mechanical properties of a higher order than those of 17-7 PH are provided. These alloys are cold formed and/or heat treated to develop desirable properties.

The designation "Condition" followed by a letter, or by letters and a number, is used throughout this paper to refer to specific metallurgical treatments. The

letter "A" designates the annealed condition, where annealing was carried out at 1950 F. Condition A 1750 indicates that austenite conditioning was accomplished at 1750 F. "T" refers to conditioning at 1400 F. "C" means transformation by cold reduction, "R" stands for refrigeration at minus 100 F and "H" indicates that final hardening has been accomplished. The number following an "A" or "H" is the temperature at which the heat treatment was given. Thus a sequence of numbers such as TH 1050 means that the metal was conditioned at 1400 F and hardened at 1050 F.

The alloy 17-4 PH is already transformed to martensite when shipped from the mill in the form of wire, rods, bars, billets and forging billets. From these forms the user fabricates or machines the alloy and then hardens it quite simply by heating at 850 to 1150 F, depending on properties desired. The alloy is fully hardened when in Condition H 900 (i.e., when the hardening treatment is carried out at 900 F). It retains high strength to 800 F.

The composition limits for 17-7 PH and PH 15-7 Mo stainless steels are much more critical than for conventional stainless steels because composition and thermal history determine the temperature at which the austenite in the steel transforms to martensite. Composition and mill-annealing operations are so controlled that a soft predominately austenitic structure is obtained. The relative ease in fabricating the two alloys is due to the austenitic condition of sheets as delivered by the producing mill.

After either alloy (Figure 1) is heated for 90 minutes at 1400 F and cooled to 60 F within one hour, transformation to martensite is practically complete. Further heating for 90 minutes at 1050 F followed by air cooling induces additional hardening. When this cycle is completed the steel is in Condition TH 1050.

The second column shows the detail of another heat treatment that produces higher strength. In this treatment, austenite conditioning is accomplished at 1750 F instead of 1400 F. Transformation to martensite requires cooling to minus 100 F and holding for eight hours. Final hardening involves heating for 60 minutes at 950 F. Steel treated in this manner is in Condition RH 950.

Data on mechanical and physical properties and other characteristics of these three stainless steels are available in the literature.<sup>2,3,5,6,7,8,9</sup>

#### Variables Affecting Corrosion Resistance

Several precautions are necessary to obtain the optimum performance from precipitation hardening stainless steels. After machining, forming and other fabrication, care must be taken to clean thoroughly all oils, lubricants and fingerprints from the surface before heat treating. Certain oils, probably because of additives, tend to "burn in" during heat treatment and affect mechanical properties. Fingerprints and other traces of chlorides lead to accelerated localized scaling during heat treatment and to subsequent difficulty in cleaning. These precautions are especially important with light gage materials. Test specimens in

TABLE 2—Corrosion Rates in Mills Per Year Based on Laboratory Tests\* (Continued)

35C 1%	HNO <sub>3</sub> , BOIL.			FORMIC ACID AT 80C		ACETIC ACID BOILING		H <sub>3</sub> PO <sub>4</sub> , BOIL.			NaOH (30%)	
	25%	50%	65%	5%	10%	33%	60%	20%	50%	70%	80C	Boil.
800(2)	8.4	58	292	451	1020	196	5.2	6	10.9	167	4.7	96
200(2)	9.6	48	125	284	2160	37	5.8	11.3	12.6	87	3.5	91
37	10.3	47.3	66	2.1	3.5	2.4	1.0	1.0	3.8	19	3.2	3.9
35	21.8	99.7	151	1.8	2.4	0.7	0.5	0.8	3.8	28	2.9	8.1
206	5.9	34.7	73	0.9	2.0	0.7	0.5	2.6	46	3.6	10.1	10.1
518	7.3	47.2	101	1.0	2.6	0.3	0.0	0.9	2.9	50	7.0	10.8
729	7.5	34.3	75	0.9	1.6	0.3	0.7	0.6	3.9	150	9.3	5.9
32	13.8	73.6	127	0.8	3.4	6.5	3.6	0.9	4.5	104	6.6	9.8
140	6.4	35.3	88	1.3	3.4	5.2	4.2	1.2	3.8	41	7.3	5.3
375	7.7	39.8	82	1.6	3.8	5.9	5.2	2.2	6.0	106	6.7	7.5
38	7.1	45.1	97	4.2	1.4	11.0	2.0	1.2	3.6	226	6.3	4.9
177	5.8	33.7	88	1.4	3.4	13.4	1.7	1.2	4.2	83	5.1	5.0
546	7.2	19.0	81	3.1	10.6	3.8	1.0	1.7	5.7	101	7.5	18.7
262	9.6	90	184	28	189	15	23	7	12	4400(I)	7.2	62
482	48	327	600	705	852(J)	54	23	6	225	635	7.2	62
550	19	116	232	15	117	17	14	12	20	306	9.8	63
823	7.2	55	85	22	54	16	25	13	16	207	12.0	45
153	18	119	228	85	359	23	31	13	132	1360(J)	5.9	60
95(I,b)	12	100	174	147.4	105	1.7	16.8	19.6	29.3	860(J,b)	7.3	43
476(I,b)	48	263	348	38.4	748(2)	110	55	200(2,b)	239(J,b)	580(J,b)	11.2	75
768(I,b)	23	81	144	1.7	9.7	2.9	14	7.7	23.6	85	18.8	67
374(J)	12	47	90	6.0	4.5	7.1	15	3.1	18.5	63	27	57
518	6	31	50	39	6.9	7.7	18	7.7	13.4	60	2.4	62
400(2)	24	96	151	6.0	6.9	7.5	4.5	14.9	35	115	2.4	67
795(2)	42	131	216	10.3	231	7.4	10.7	29.8	66	347	2.3	81
47.6	4.9	67.7	148	5.0	18	3.1	14.4	12.9	32	353	3.4	40
183.3	26.6	148	257	178	527	3.5	12.2	28	106	496	4.9	45
322(J)	15.8	59	112	3.7	1.4	3.4	10.6	6.3	25	161	7.4	67
353(J)	8.5	40	73	6.3	3.8	10.0	5	5	14	142	7.8	57
494(J)	6.1	26.7	51.6	6.4	3.5	1.7	14.1	19	12	208	9.4	64
184	16.8	68.4	121	2.6	4.5	3.6	1.6	737	57	716	5.0	48
64	22.8	133	316	32	49	3.9	3.6	7.1	19.1	218	3.3	149
280	119	512	748	161	123	3.0	33	15.4	97.5	600(J)	4.3	142
152	36	128	210	7.3	74	7.6	6.8	22.2	52.3	277	3.3	139
240	2	4	10(c)	81	100	300	250(d)	2	7(e)	32(e)	0.0	68(I)
20.8	1.2	3.6	7.2	4.0	3.3	3.3	2.3	1.7	10.9	35	0.8	21.7
13.9	1.2	2.4	7.2	4.2	32.7	1.9	29.4	1.4	6.3	42	0.9	13.3

b Cracked during test.

c Rate increased from period to period. Rate is average for five periods.

d Rate is rough average for activated periods.

(I) Rate is average for number of periods indicated by italic type in parenthesis.

\*See References 10, 11 and 12.

particular, because of their small size and need for individual handling, call for even more care than production items.

Scale or oxide films should be removed by wet grit blasting or similar mechanical process rather than by pickling. Pickling may cause grain boundary attack if not carefully controlled and can adversely affect corrosion resistance and stress cracking characteristics.

Care also must be exercised with furnace atmospheres used during heat treatment. Conditions leading to small amounts of surface carburization or nitriding will adversely affect corrosion resistance as well as mechanical properties.

Finally, a most important consideration is that corrosion resistance as well as mechanical strength depends on the heat treatment applied. This will be shown in the sections that follow.

#### General Corrosion Data

During the past ten years hundreds of accelerated laboratory corrosion tests have been conducted on the precipitation hardening stainless steels for comparison with rates of other grades. Such tests have been conducted in:

1. One, 2 and 5 percent sulfuric acid.
2. One-half and 1 percent hydrochloric acid.
3. Twenty-five, 50 and 65 percent nitric acid.
4. Five and 10 percent formic acid.

5. Thirty-three and 60 percent acetic acid.

6. Twenty, 50 and 70 percent phosphoric acid.

7. Thirty percent sodium hydroxide.

As chemically pure laboratory reagents were used, the data are useful chiefly as a guide as to comparative performance with other materials under identical conditions. Typical findings are given in Table 2. Listings in the table indicate whether the corrosion rate was determined on bar or on sheet stock. Because of a relatively large proportion of end grain and side grain, corrosion rates for small bar specimens will sometimes be higher than for sheet specimens in the same medium.

These data indicate that the precipitation hardening stainless steels in their heat treated conditions have better corrosion resistance than hardened chromium stainless steels such as Type 431. 17-4 PH is equal to Type 304 in many of the media shown. However, PH 15-7 Mo and 17-7 PH show less corrosion resistance in these accelerated laboratory tests than Type 304.

#### Fuming Nitric Acids

With the use of fuming nitric acids as fuels for rocket engines for missiles, high strength corrosion resisting materials are needed for tanks and thrust chambers. Neither red nor white fuming acid has much in common with 65 percent boiling nitric acid.<sup>13</sup> The corrosive

attack is of an entirely different order of magnitude.

Fontana<sup>14</sup> reports rates for austenitic stainless steels in white fuming nitric acid at 122 F are slightly lower than in the red acid. These rates vary between 12 to 70 mpy per year, depending on grade. At 160 F the rate increases roughly four to five-fold.

Other data indicate 17-7 PH (TH 950) has a very low corrosion rate, about 1 mpy at room temperature, but that it has a very high rate of about 300 mpy at 160 F.

Fontana also has reported rates for many grades of stainless steel in red fuming nitric acid at 122 F. For the austenitic grades these were generally in the range 16 to 130 mpy depending on grade. At 160 F the range is 61 to 272 mpy, depending on grade. Kaplan and Andrus<sup>15</sup> report lower rates for the stainless steels at 50 to 80 F and much higher rates at 250 to 300 F. Thus an increase in temperature results in a marked increase in corrosion rate.

17-7 PH, Condition TH 1050, is less resistant to the corrosion action of red fuming nitric acid than Types 304 and 347.<sup>16</sup> 17-7 PH usually corrodes at a rate of 250 to 300 mpy at 120 F. At 160 F, 17-7 PH corrodes at a still higher rate. These rates are based on tests that ran 30 days or less.

Phelps, Lee and Robinson<sup>17</sup> discuss in detail the effectiveness of hydrofluoric acid as an inhibitor of corrosion by red fuming nitric acid. They point out that 17-7 PH (TH 1070) corroded at a high

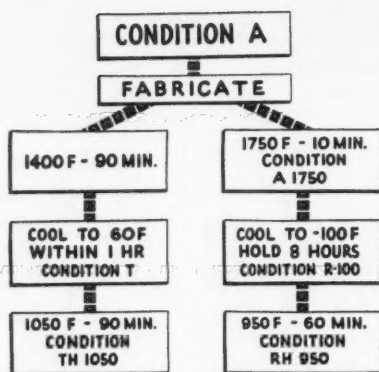


Figure 1—Two heat treatment series for 17-7 PH and PH 15-7 Mo.

rate when exposed to red fuming nitric acid containing 12 percent  $\text{NO}_2$  at 120 and 160 F. Powerful inhibition in both liquid and vapor phases is obtained by addition of hydrofluoric acid. The addition of 0.75 percent hydrofluoric acid reduced the 120 F corrosion rate to 1.7 mpy in the liquid phase and 0.16 mpy in the vapor phase. Effective inhibition also occurred at 160 F. Thus, 17-7 PH is considered highly satisfactory under conditions where hydrofluoric acid can be used in red fuming nitric acid.

#### High Temperature-High Purity Water

During the past few years the subject of corrosion resistance of materials to high purity water at high temperatures has been of great importance in the atomic power field. Laboratories associated with atomic energy work have published a considerable amount of data.

Breden and associates<sup>18</sup> show favorable results on 17-4 PH and 17-7 PH in oxygenated water at 500 F, whereas results on chromium hardenable stainless steels and many other alloys were not so favorable.

Roebuck<sup>19</sup> presents a tabulation of corrosion resistance of 13 families of metals and alloys to water from 200 to 680 F. The austenitic stainless steels are among those materials showing highest resistance over the entire range. The precipitation hardening stainless steels have highest resistance at temperatures to 500 F and show better performance than the chromium stainless steels.

DePaul<sup>20</sup> and Friend<sup>21</sup> refer to stress cracking of 17-4 PH and 17-7 PH springs in 500 to 600 F water. These as well as other hardenable materials are subject to stress cracking in some environments. In this regard choice of aging treatments, as pointed out by Bloom,<sup>22</sup> can be a most important factor.

Boyd and Pray<sup>23</sup> studied the behavior of stainless steels, both hardenable and nonhardenable in degassed supercritical water at 800, 1000 and 1350 F at 5000

psi pressure. They report that all the alloys evaluated had excellent resistance to corrosion at 800 F. 17-4 PH, 17-7 PH and Hastelloy F were the most resistant materials at 1000 and 1350 F.

#### Nitriding

When increased resistance to wear and galling has been needed in hardenable stainless steels, nitriding has been used to increase hardness. During the past 20 years Armco has conducted a number of accelerated laboratory corrosion tests on stainless steels of all kinds with nitrided cases. The recent literature contains additional interesting corrosion data in this regard. These findings indicate that nitriding reduces corrosion resistance in all media investigated.

#### Sea Water

While the stainless steels all show low corrosion rates in sea water, they can be subject to serious pitting corrosion. Pitting is often initiated beneath substances lying on or attached to the surface, or in crevices. Once started, this so-called contact or crevice corrosion paves the way for intense passive-active cell action. Large areas of the stainless steel that remain uncorroded or passive contribute to greatly accelerated attack in shielded areas. This means that unless stainless steel is washed frequently or kept clean in association with stagnant sea water exposure, serious localized attack can result. This applies to any grade of stainless steel, with Types 316 or 317 being the most resistant. Cathodic protection, grease films, or paint systems can be used to prevent this kind of corrosion.

Sea water exposure tests<sup>24,25</sup> still in progress have compared 17-4 PH and 17-7 PH with Types 431 and 302. Even though the 17-7 PH in these tests had been aged at 900 F, which is one of the less favorable conditions for corrosion resistance, its rate of corrosion is in the order of 3 mpy. The rate for the several grades are as shown in Table 3.

These rates are all low and can be misleading if considered alone. The weight loss was almost entirely from crevice corrosion at the mounting washers with some pitting and etching beneath deposits. The least attack occurred on Type 316. Generally the exposure of stainless steels in stagnant or low velocity sea water must be made with caution. At high velocities, crevices and deposits are less troublesome.

Where formation of deposits and presence of crevices is not a problem, 17-4 PH has shown promise. Recent work

suggests that the corrosion fatigue strength of this alloy in mildly saline as well as sea water is superior to that of the standard hardenable types. Boat shafts of this grade have been operating in Chesapeake Bay for three years without evidence of pitting or crevice corrosion.

#### Atmospheric Corrosion Resistance

The precipitation hardening stainless steels show greater resistance to corrosion in marine and mild industrial atmospheres than the hardenable chromium stainless steels. For example, Figure 2 illustrates appearance of specimens exposed four months at three locations. In the mild industrial atmosphere at Middletown there has been no rusting on PH 15-7 Mo or 17-7 PH, Condition RH 950. However, Type 422 modified, hardened and stress relieved at 900 F, shows some rusting. At Kure Beach, North Carolina, in the lot 800 feet from the ocean all three materials have stained or rusted to some extent. The PH 15-7 Mo is better than 17-7 PH, and both are considerably better than 422 modified. In the more severe exposure 80 feet from the beach, this relationship between materials is unchanged, although the intensity of attack is greater. These specimens have shown how atmospheric attack is related to the environment.

Heat treatment of the precipitation hardening alloys results in the formation of a basically martensitic structure and these alloys, like the martensitic hardenable chromium steels, will show variations in corrosion resistance as the tempering, stress relieving, or aging temperatures are varied.

In a mild industrial atmospheric environment the PH alloys show no visible corrosion, as in Figure 3. However, an alloy such as 422 modified does corrode. Tempering at 900 F appears to produce poorer corrosion resistance in Type 422 modified than tempering at 700 or 800 F.

In the marine atmosphere at Kure Beach some effects of heat treatment and alloy composition become apparent. Figure 4 shows specimens exposed in the 800-foot lot four months. PH 15-7 Mo (TH 1050) shows a general stained condition with few rust spots. It appears worse than 17-7 PH (TH 1050). However, in Condition RH 950, PH 15-7 Mo shows less staining than 17-7 PH and is comparable with both materials in their best corrosion resistant condition which is CH 900. Not shown in the photograph is full hard Type 301 that was corroded only slightly less than 17-7 PH and PH 15-7 Mo in Condition

TABLE 4—Mechanical Properties of Materials Exposed Four Months At Kure Beach, North Carolina

SAMPLE	Original Properties			Percent Change in Strength				Percent Elongation After Exposure	
	.2% YS psi	TS psi	%E 2"	800' Lot		80' Lot		%E	80'
				YS	TS	YS	TS		
PH 15-7 Mo	TH 1050	202,800	215,800	8	-0.5	-1.3	-5.5*	8	6
	RH 950	215,800	242,600	6	+2.8	+0.7	-1.0	7	6
	CH 900	238,100	251,000	1	+0.5	-0.5	+1.4	2	2
17-7 PH	TH 1050	186,200	197,400	7	+0.6	+1.5	+0.9	8	8
	RH 950	211,000	228,600	6	-0.6	+0.4	-2.8	6	6
	CH 900	259,000	272,400	1	+0.2	+0.2	+0.2	2	2
422-Mod. 1850 + 700	800	185,700	240,400	6	-8.6*	-6.7*	-5.3*	6	6
	800	189,400	239,100	7	-6.7*	-8.0*	-14.1*	5	6
	900	182,200	235,500	7	-1.1	-4.7*	-3.9*	7	8
Type 301 Full Hard	169,200	209,100	10	-1.4	-3.0*	-0.4	-0.4	10	11

\* Changes greater than 3 percent original strength shown in bold type.

TABLE 3—Corrosion Rates of Metals in Sea Water

Material	Treatment	Time Exposed	Corrosion Rate
17-4 PH 410	H900	6 years	1 mpy
	Hardened and Tempered	6 years	3 mpy
431	Hardened and Tempered	7 years	2.5 mpy
316	Annealed	7 years	0.2 mpy
302	Annealed	7 years	0.8 mpy
17-7 PH	TH 900	7 years	3 mpy



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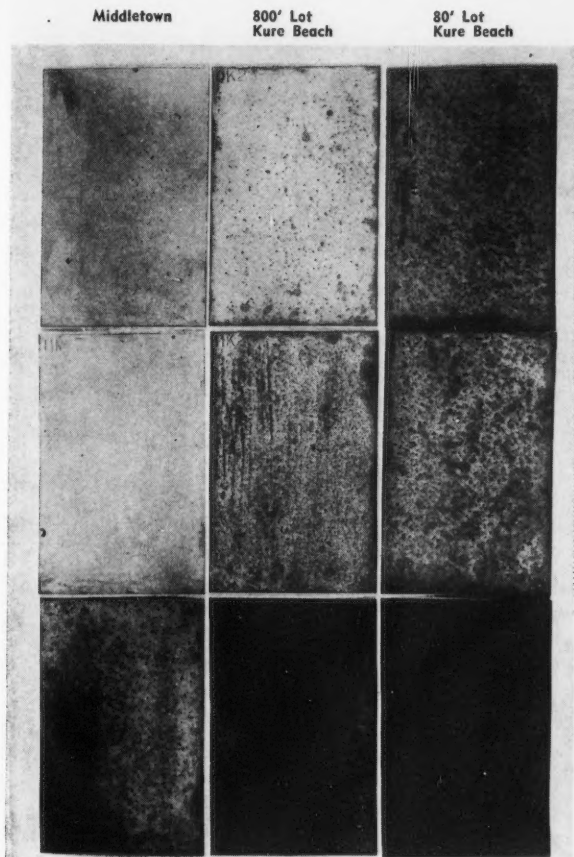


Figure 2—Specimens exposed four months. Top row: PH 15-7 Mo RH 950; middle row: 17-7 PH, RH 950; bottom row: 422 Mod., 1850 + 900 F.

CH 900. Type 422 modified tempered at 700, 800 and 900 F shows considerable areas of rough red rust. The specimen tempered at 900, which has about the same tensile strength as PH 15-7 Mo (RH 950) is nearly 100 percent covered with rust.

In the more severe exposure, in the 80-foot lot, Figure 5, the corrosive attack has increased. Again Type 422 modified tempered at 900 is the most severely attacked, and is 100 percent red-rusted. 17-7 PH, Condition TH 1050 appears slightly better than PH 15-7 Mo, TH 1050. PH 15-7 Mo, RH 950, again compares favorably in appearance with Condition CH 900.

Based on the appearance of these specimens, the materials can be placed in a relative order from best to worst, as follows:

1. Type 301 full hard.
2. 17-7 PH and PH 15-7 Mo CH 900, PH 15-7 Mo RH 950.
3. 17-7 PH TH 1050 and RH 950.
4. PH 15-7 Mo TH 1050.
5. 422 modified—Tempered 700.
6. 422 modified—Tempered 800.
7. 422 modified—Tempered 900.

Most of the attack on the PH 15-7 Mo and 17-7 PH was staining.

Some engineers may regard the appearance of these specimens as indicative of relatively severe corrosive attack. What is important, though, is whether or not such attack caused any deterioration of tensile properties. Previous work

had shown that six months exposure in the 800-foot lot resulted in no loss of tensile strength of the PH alloys; data were not available for similar exposures in the 80-foot lot. Opinions have been expressed that the beach exposure is more representative of conditions encountered at some air bases and on board aircraft carriers. Samples were exposed but were removed after four months because of time limitations. Tensile blanks were machined from the corroded specimens and mechanical properties compared with uncorroded stored samples. These data are in Table 4.

Corrosion resistance, as measured by changes in tensile properties agrees with conclusions based on appearance. Yield and tensile strength data on high strength materials are subject to variation, even between like materials. Authorities suggest that such data that vary no more than 2-4 percent are checks. Therefore, only changes greater than 3 percent of the original strength are considered to be significant.

These data show that Type 422 modified suffered significant changes at both marine locations. 17-7 PH in Conditions TH 1050, RH 950, and CH 900, and PH 15-7 Mo in Conditions RH 950 and CH 900 showed no loss in strength. PH 15-7 Mo in Condition TH 1050 showed a significant change at the 80-foot lot only. This parallels conclusions based on appearance of this material. These alloys showed no changes in ductility, as measured by tensile elongation.

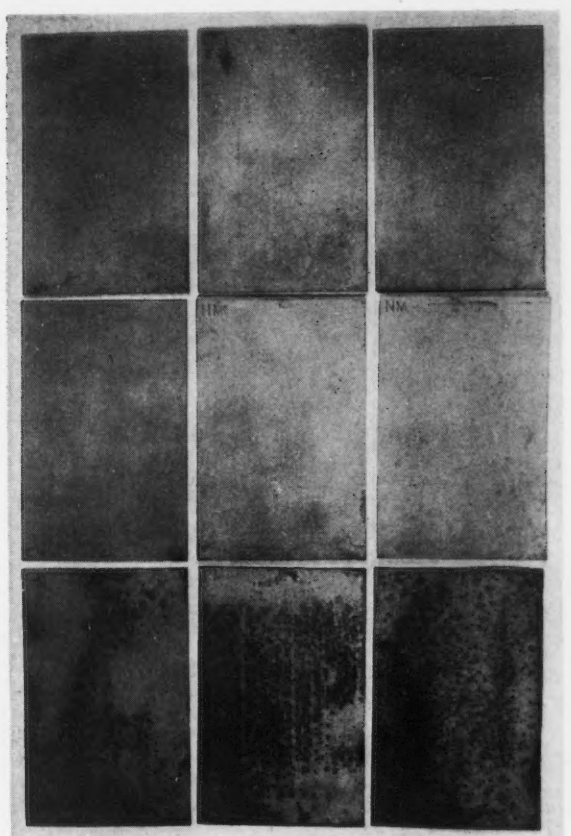


Figure 3—Specimens exposed four months at Middletown, Ohio. Top row: PH 15-7 Mo TH 1050, RH 950, CH 900; middle row: 17-7 PH TH 1050, RH 950, CH 900; bottom row: 422 Mod. 1850 F plus 700 F, 800 F, 900 F.

Tests such as these represent severe service in that test specimens receive no maintenance between exposure and removal. Corrosion products and concentrated sea salts continue to accumulate, particularly on groundward surfaces where they are never washed away by rain. It can be seen that these data demonstrate a good performance of the material, even under conditions unquestionably more severe than would be encountered under the most unfavorable service conditions.

### Galvanic Corrosion

In order for galvanic corrosion to occur in any system, three fundamental requirements must be met. First of all there must be metallic contact between the two metals involved. Secondly, an electrolyte or solution that will carry a current must be present and wet both metals. Rain water itself is not enough of an electrolyte to be much of a cause for concern, but rain water in contact with a surface on which there are salty deposits or sea spray or sea water conceivably could lead to trouble. Thirdly, a potential difference must develop between the two materials involved. If this potential difference falls off, galvanic effects likewise fall off. If any one of these conditions is absent, galvanic corrosion cannot occur.

The question arises from time to time as to what can be expected in the way of galvanic or bi-metal corrosion relationships between a hardenable chro-

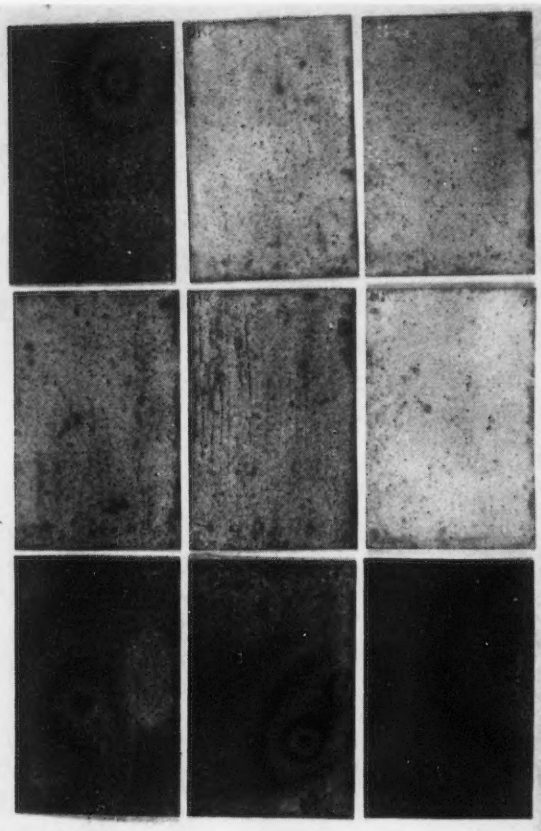


Figure 4—Specimens exposed four months at 800 foot lot, Kure Beach, North Carolina. Top row PH 15-7 Mo TH 1050, RH 950, CH 900; middle row: 17-7 PH TH 1050, RH 950, CH 900; bottom row: 422 Mod. 1850 F plus 700 F, 800 F, 900 F.

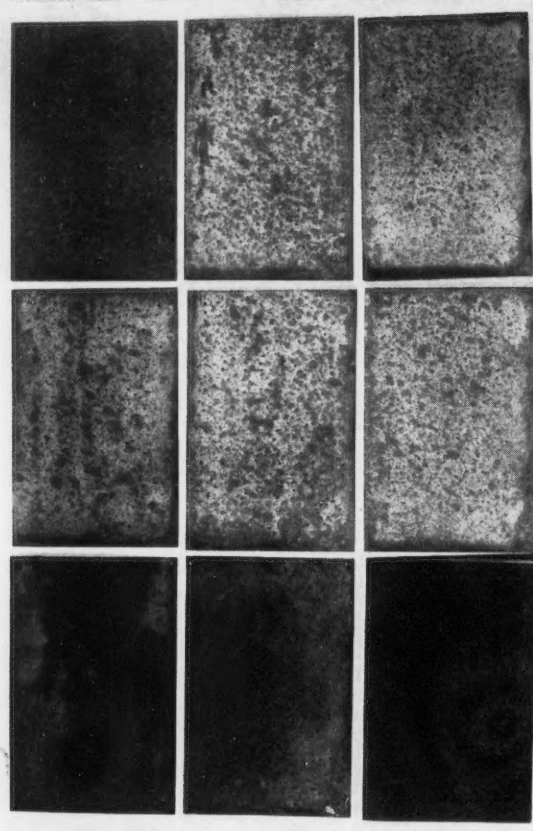


Figure 5—Specimens exposed four months at 80 foot lot, Kure Beach, North Carolina. Top row: PH 15-7 Mo TH 1050, RH 950, CH 900; middle row: 17-7 PH TH 1050, RH 950, CH 900; bottom row: 422 Mod. 1850 F plus 700 F, 800 F, 900 F.

mium or a precipitation hardening stainless steel and another metal or alloy in a system. The precipitation hardening stainless steels are more noble than many other metals and alloys in a great many environments. Thus other metals and alloys could suffer accelerated corrosion from such effects. Conversely, the stainless steel also might suffer when in contact under the right conditions with a more noble metal or alloy.

Huston and Teel<sup>20</sup> in 1952 published information on observations of potentials of hardenable stainless steels, including the Armco precipitation hardening alloys in flowing sea water. Their work provides information relating their potential values to those of other common alloys, therefore indicating possible galvanic effects in this specific medium.

While galvanic corrosion is recognized as a possibility when a more noble material is in direct contact with a less noble one, actual cases of trouble coming to the attention of the authors have been extremely rare. This may be due to the fact that designers are well educated in this respect. It also may mean that galvanic effects are rarely severe enough to cause concern.

#### Stress Cracking

The hardenable straight chromium stainless steels are known to be subject to spontaneous fracture when stressed and exposed to some corrosive environments. Likewise, under some conditions,

the precipitation hardening stainless steels also may fail by stress cracking. The tendency to fail appears to be associated with the type of stainless steel, its hardness, the level of applied tension stress, and the environment.

Much work has been done by the Armco Research Laboratories to study stress cracking characteristics. The results of one such comprehensive investigation were reported in the literature in August 1955 by Bloom.<sup>21</sup> He compares low alloy, hardenable chromium stainless, precipitation hardening, austenitic and austenitic-hardenable stainless steels in a number of media known to induce stress corrosion cracking. These media include acetic acid-hydrogen sulfide, acetic acid-hydrogen sulfide-sodium chloride, 20 percent salt spray, 6 percent sodium chloride solution, and industrial and marine atmospheres. The study includes the effect of tempering treatments on chromium hardenable grades, and of aging variables on the precipitation hardening alloys.

Additional stress cracking data have been partly accumulated on some of the materials previously discussed in the atmospheric corrosion section. In the mild industrial atmosphere at Middletown, both 17-7 PH and PH 15-7 Mo in Conditions TH 1050, RH 950 and CH 900 have shown complete immunity to failure even when stressed at 90 percent of their 0.2 percent yield strength and exposed 21 months.

Failures have occurred in a marine atmosphere. Both 17-7 PH and PH 15-7 Mo, Condition TH 1050 and CH 900 did not crack at 50 percent yield (approximately 100,000 psi) after 21 months. Even at 75 percent neither material in CH 900 had cracked in 21 months. In Condition RH 950 failures occurred at 50 percent yield stress, but the data are not complete enough to permit comparisons between 17-7 PH and PH 15-7 Mo. An observation of possible significance was that stress cracking failures of PH 15-7 Mo were almost entirely by cracks that did not result in complete fracture of the test specimen. With 17-7 PH, however, failures generally resulted in complete fracture of the specimen.

#### Brazing and Welding

This presentation would not be complete without mentioning brazing and welding of these materials and corrosion resistance of resulting structures.

17-7 PH honeycomb panels have in the past been brazed with 85 percent silver-15 percent manganese silver brazing alloy. While certain laboratory tests were negative, there has been some evidence of crevice corrosion leading to separation of brazed joints. For this reason emphasis has shifted to a 92.5 percent silver-7 percent copper-0.5 percent lithium brazing alloy. Laboratory tests by one brazing alloy manufacturer have indicated relief from crevice corrosion effects.

Specimens of 17-7 PH sheet treated to Condition TH 1050 after inert gas shielded arc welding have been exposed to the atmosphere at Middletown, Ohio and in the 800-foot lot at Kure Beach, North Carolina for more than three years. No accelerated corrosion has been observed in welds or weld affected zones.

### Summary

In this presentation special attention was given to three precipitation hardening stainless steels. The need for these materials of construction was shown. Heat treating sequences and resulting properties were described. Consideration was given certain variables affecting corrosion resistance. Finally, a considerable amount of corrosion data was presented comparing these three steels with other stainless grades. These data covered a rather complete cross-section of environments from which the corrosion resistance of the precipitation hardening stainless steels could be evaluated. It was obvious that they showed better corrosion resistance than the hardenable chromium grades. Performance in marine

and in mild industrial atmospheres should be of particular interest to aircraft and missiles engineers.

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Any discussions of this article not published above  
will appear in the December, 1958 issue



# The Distribution of Soil Conductivities And Some Consequences\*

By GORDON N. SCOTT\*

## Introduction

IN A RECENT paper by the author,<sup>1</sup> use was made there, without proof, of the normality of the probability distribution of the logarithms of soil conductivity. It is here shown empirically that the logarithms are indeed normally distributed in an impressive array of soils.

There is no inquiry in the present paper into the meaning of the several kinds of measurements of soil conductivity in common use and no employment of advanced statistical methods of analysis. The immediate objective is simply to establish the fact that soil conductivities are normally distributed. However, to widen reader interest, many of the almost limitless practical consequences of the relationship are discussed.

## Normal Distribution<sup>2</sup>

The analytical power of mathematical statistics is extraordinary. This power arises from the concept of probability which has application from chance events of the simplest kind such as the appearance of a head or tail on the toss of a coin, to highly complex happenings.

The theory of probability is built upon a few simple basic laws. It can be said, by way of definition, that the probability of an outcome of a chance event lies in the closed interval zero to one, where both extremes may represent certainty of an assigned kind. Where the probability of an event is continuous it is demanded that

$$F(x) = \int_{-\infty}^{+\infty} f(x) dx = 1$$

The function,  $f(x)$ , has a special meaning in statistics. As the equation shows, the integral of the function over the entire continuous range of the variate  $x$  must be one. When this demand upon  $f(x)$  is met the function becomes the "probability density," since  $f(x)dx$  gives the proportion of the total outcomes falling in the interval  $dx$ . The term is indeed well chosen.

The probability that the variate will occur in an interval from  $a$  to  $b$  will be the integral between these limits. The probability that the variate will be less than (greater than) any value  $c$  will be the integral between the limits  $-\infty$  and  $c$  ( $c$  and  $+\infty$ ). Thus

$$P(-\infty < x < c) = \int_{-\infty}^c f(x) dx \\ = 1 - \int_c^{+\infty} f(x) dx = F(c)$$

and for the range of  $x$  between  $a$  and  $b$

$$P(a < x < b) = F(b) - F(a)$$

In a very wide variety of natural phenomena the distribution of an attribute is such that the probability density curve is symmetrical and has the semblance of a bell. Such distributions are said to be "normal" if they can be represented by the density equation

$$f(x) = (1/\sigma\sqrt{2\pi})e^{-(x-\mu)^2/2\sigma^2}$$

where  $\mu$  is the mean or average value of the variate  $x$  and sigma  $\sigma$  is the standard deviation—a measure of dispersion of the data.

The equation shows the effect of a change in  $\mu$  is simply to slide the bell-shaped probability density curve to right or left along the axis of  $x$ . The effect of a change in standard deviation is to flatten the curve or to steepen it and accentuate the peak or mode as it is called. These two parameters, therefore, characterize normal distributions.

If it is known that a set of data behaves like a sample from a normal distribution it is possible to estimate the parameters of the population or parent distribution from which the sample is considered to have been derived and with confidence apply the applicable analytical procedures of mathematical statistics.

The normal distribution is so well known and so important in mathematical statistics that it is often for abbreviation designated by the symbol<sup>3</sup>

$$N(x; \mu, \sigma)$$

which can be read "the variate  $x$  is normally distributed with mean  $\mu$  and standard deviation  $\sigma$ ." In this simple expression for the normal distribution the variance  $\sigma^2$  is ordinarily used but the square root will be used here.

With this brief explanation of what is meant by a normal distribution it will be shown that the logarithms of soil conductivity (resistivity) are normally distributed as shown below:

$$N(n, \log \rho; \mu, \sigma)$$

In this notation the additional information on the size of sample  $n$  is given. The statistics  $\mu$  and  $\sigma$  will be called the soil parameters.

## Presentation of Data

All of the data presented unless otherwise noted were taken by the author using the four-electrode method of Wenner.<sup>4</sup>

In Table 1 nine soil resistivity measurements are listed in Column 2 in order of increasing magnitude. Corresponding conductivities are given in Column 3

## Abstract

It is shown without resort to theory that the logarithms of soil conductivity are normally distributed in an impressive range of soils. This discovery opens a new field of investigation for corrosion engineers and makes possible better engineering in soil corrosion mitigation. A number of practical applications of the relationship are discussed.

Considerable soil resistivity data are reported. No inquiry is made into the meaning of the several kinds of measurements of soil conductivity in common use and no employment is made of advanced statistical methods of analysis. 4.5.1

and the cumulative frequency in Column 4. Field test numbers are shown in Column 1. The associated probability calculated from the cumulative frequency and from the size of sample plus 1, appears in Column 5. The percentage is used instead of probability. The reason for this is apparent in Figure 1 where the data are plotted on logarithmic probability paper with percentage probability as abscissa and the logarithm of resistivity as ordinate.<sup>4</sup> While the ordinate gives the resistivity directly in ohm-centimeters, the scale is logarithmic. Similarly, the integral of the bell-shaped normal probability density curve has been stretched in the graph so that a normal distribution plots as a straight line. The data of Table 1 fall close to the straight line which has been drawn in the figure and therefore they may be considered a sample from a normal population.

In estimating the probabilities in Table 1, a denominator one greater than the size of the sample of 9 measurements, ( $n+1=10$ ), was used. Referring to the straight line in Figure 1, if it is desired to estimate resistivities at probabilities of 0.1 intervals (10 percent), one could only get 9 values since the tenth would be at 100 percent or off the diagram to the right at plus infinity. The chart range is from 0.01 to 99.99. Thus the tenth measurement would be lost. If the conductivity measurements, which are given in Table 1, were plotted in order of increasing magnitude instead, one would make use of the tenth measurement but not the first, since it would then be off the chart at infinity. To escape this dilemma and to make it possible to utilize all the experimental data, Gumbel<sup>5</sup> suggested that the denominator be one greater than the size  $n$  of the sample, since the error thus involved would be small.

The coordinate lines of Figure 1 detract attention from the curve and add nothing to an appreciation of the data for the simple objective of this paper. In further illustrations, therefore, the coordinate lines are omitted and only the 50 percent abscissa is shown together with a principal ordinate and the size of sample. If it is desired to estimate the range in data it is easy to

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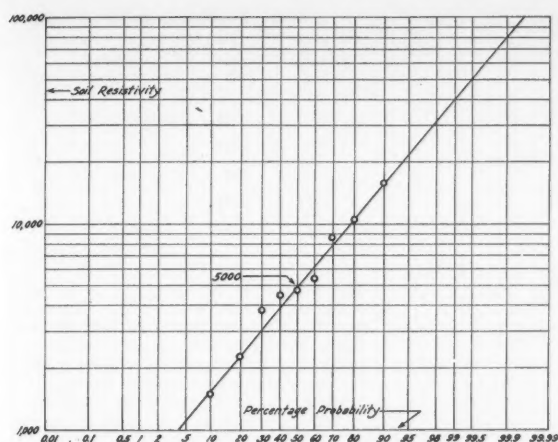


Figure 1—The nine soil resistivity measurements and their estimated probabilities conform to a straight line on log-probability paper. The mean value is approximately 5000 ohm-cm.

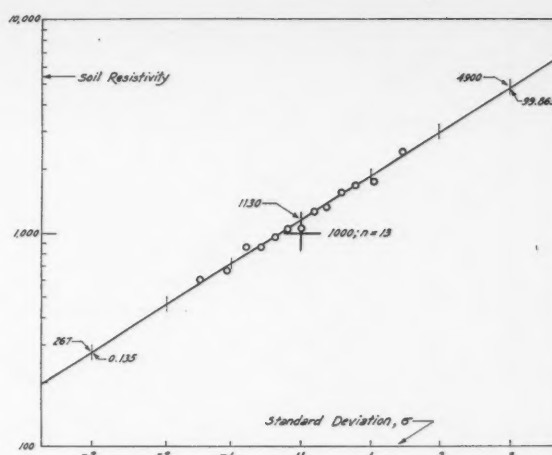


Figure 2—The thirteen soil resistivity measurements are normally distributed. Standard deviation is used as abscissa instead of probability.

TABLE 1—Ordered Soil Resistivities and Estimated Probabilities\*

Test No.	Resistivity	Conductivity	Cumulative Frequency	Probability (Percentage)
4	1500	667	1	10
5	2300	435	2	20
9	3800	263	3	30
1	4500	222	4	40
7	4700	213	5	50
2	5400	185	6	60
3	8600	116	7	70
6	10400	96	8	80
8	16000	62.5	9	90
n+1			10	100

\* Farragut Drive School, Culver City, California.

NOTE: Resistivity is in ohm-centimeter; conductivity in micromho per centimeter. (1000 ohm-cm. is equivalent to 1000 micromho per cm.) Tests were made in February 1957 with a Model 599 Megger Earth Resistance Tester.

TABLE 2—Probability and Standard Deviation\*

Standard Deviation	Probability (Percentage)	Approximate Resistivity	Resistivity Log
3	99.865	4900	3.6902
2	97.725	3000	3.4771
1	84.134	1850	3.2672
Mean	50.000	1132	3.0539
-1	15.865	695	2.8420
-2	2.275	435	2.6385
-3	0.135	267	2.4265

$N(13, \log; 3.05385, 0.2109) \equiv N(13, \log; 1132, 1.625)$

\* El Marino School, Culver City, California.

make a quick estimate of the probability of the extremes by adding one to the sample size and taking the reciprocal. Note that the probabilities are symmetrical with respect to the 50 percent abscissa. It is not even necessary in a plot of the data to identify the probability and log resistivity axes since the probability is always the abscissa.

The scale lines have been omitted in Figure 2 in which 13 soil resistivity measurements ranging from 600 to 2400 ohm-centimeter are shown with respect to coordinates, 50 percent and log 1000 ohm-centimeter. These data show clearly that the logarithms are indeed normally distributed. If a sample consisting of  $n$  soil resistivity measurements is representative of the soil area over which the measurements were made and if the logarithms of the measurements are normally distributed, then the soil is

said to be "uniform," irrespective of the magnitude of the soil parameters. These thirteen measurements evidently were taken over a uniform soil. The word *uniform* is here used in the sense of conforming to one rule or mode; it is used in its more familiar meaning later in reference to the Dixon soil.

The short vertical lines on the curve are located at plus and minus, 1, 2 and 3 times the standard deviation, which measure of dispersion has been used as abscissa instead of probability to which it is related (see Table 2).

In Figure 3 are shown 118 measurements taken for the Hawaiian Pineapple Company on the island of Lanai, in the Hawaiian Islands. It is impossible to show all 118 resistivity measurements with their associated probabilities on the diagram because the probabilities are too crowded in the middle of the curve.

Many of the data, particularly probabilities associated with recurrent values of soil resistivity, are, therefore, omitted for clarity. This also is true of other curves to be presented.

It may be concluded from the curve in the figure that the soil in which the irrigation lines lie is substantially uniform, with logarithms of resistivity, therefore, conforming reasonably to a normal distribution.

Four leaks occurred in the pipeline in the area covered by the measurements and these are located with respect to the corresponding soil resistivity by two black dots and four arrows. Two leaks occurred at the next to the lowest measured resistivity, and two at higher values. Note that the leaks occurred at resistivities substantially below the mean of approximately 3000 ohm-cm which is the resistivity on the curve associated with the abscissa at 50 percent.

Two facts of interest in the three curves presented so far are that the means and slopes are different. The difference in slope indicates that the standard deviations of the several sets of data are different.

Figure 4 shows in a more striking manner difference in location of curves with respect to the ordinate (different means) and difference in slopes (different standard deviations). The data range from almost 100 to over 100,000 ohm-centimeters. The large circles on and at the right of the curves with the numerals in them serve to identify the data and to give the number of measurements (size of sample). The soils in all six cases are different and have resistivities which yield a normal distribution of their logarithms.

The 21 very low resistivities which determine the bottom curve were taken at Lemoore, California, for the U. S. Navy. The data for the curve next above marked "32," were also taken for the Navy, over a large area near Dixon, California. These latter data indicate a remarkably uniform type of soil with respect to resistivity in that the curve is relatively flat which corresponds to a small standard deviation. If the measurements were all of the same value the curve would be horizontal and the standard deviation would be zero.

The 90 measurements of the topmost curve were taken in 1942 for the Barn-

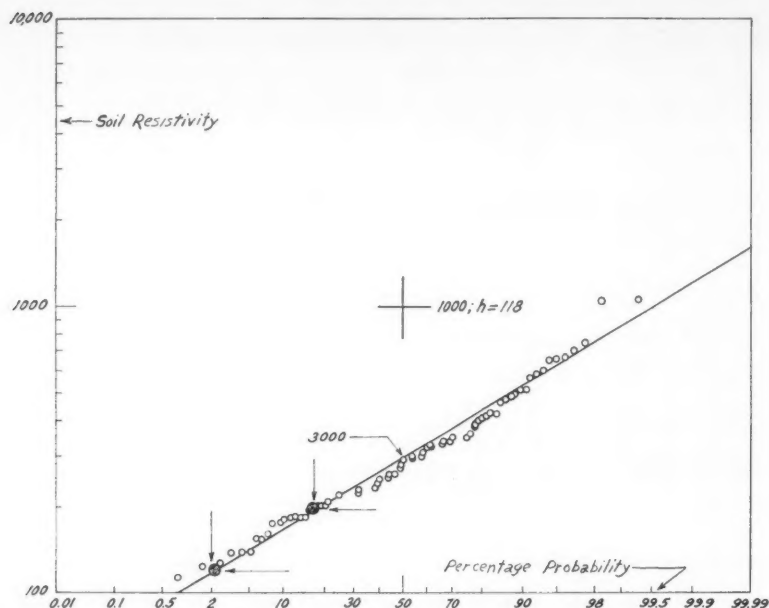


Figure 3—The soil resistivities conform well to a straight line. The black dots indicated by the arrows show with respect to resistivity where leaks have occurred on the 18 miles of pipeline.

dall Oil Company at Val Verde, California. The mean and standard deviation of this curve are both large. The 25 measurements of the next lower curve were made for the Bechtel Corporation in 1953 over the right-of-way of a water supply line for a power plant at Castlegate, Utah. Curves 81 and 156 were drawn from data taken, respectively, at the Naval Supply Annex on Rough and Ready Island near Stockton, California, in 1952, and in 1946 for Yost and Gardner, Consulting Engineers, in and for the City of Phoenix, Arizona. The latter data are displayed in skeleton form since the 156 measurements could not as earlier explained all be conveniently plotted in the figure.

#### Some Consequences and Practical Applications

From the data presented, which are representative of many of the author's sets of similarly conforming data, it can be concluded that in a uniform soil the logarithms of soil resistivity are normally distributed. Additional examples of the relationship will be given in the following paragraphs in which will be discussed certain consequences of this fact.

The author can hardly consider a problem in underground corrosion without wondering first what the soil is like.

To begin with, the resistivity of a "uniform" soil cannot be characterized by a single number such as the mean. But the soil can be well described by two parameters if the logarithms are normally distributed. In fact with known soil parameters it is simple to draw the probability curve, and, from it, to duplicate almost exactly the values which would be found by measurement in a sample of nearly any elected size.

The probability chart offers an excellent method of presenting soil resistivity data.

The normality of the log resistivity distribution almost dictates how a large sample of data should be classified with respect to resistivity and corresponding corrosiveness. Since it is the logarithms

which are normally distributed the resistivities themselves must be classified according to a geometrical progression, the simplest of which would be the ratio of two to one. Conductivity is the reciprocal of resistivity and since logarithms of the latter are normally distributed it follows that logarithms of conductivity are also normally distributed. It is the resistivity which is measured in the field but it is the conductivity which in theory is directly proportional to corrosion. Accordingly both resistivity and conductivity are needed and logarithms of these quantities may be used interchangeably in a probability chart (see Table 1). Since a resistivity of 1000 ohm-cm is equivalent to 1000 micromho per cm the value 1000 appears to be a natural pivot for a classification scheme. Thus in accord with the above and the author's current usage, a central portion of the arrangement would be as shown in Table 3. This arbitrary classification should not be used in partitioning an area with respect to corrosiveness but the more natural segregation suggested by Figure 6, to be explained later, should be used. Thus, for the data shown in the five other figures, there is little to invite any arbitrary separation or mapping of soils, while three classifications could be used to map the Corpus Christi soils.

Since the logarithms conform to a normal distribution, the vast mathematical theory on the subject in the literature is applicable to corrosion problems which involve soil conductivities. A very simple illustration is the estimation of the mean of a sample. Since for the normal distribution the mean, the median (where the probability is one-half) and the mode (where the derivative of the probability density is zero—the peak of the bell-shaped curve) are all equal, the mean and mode can be determined from the median. The median can be found more quickly if the data have been ordered as in Table 1 or the value read more closely from a chart if the data have been plotted. Furthermore from

TABLE 3—Classification of Soils

Resistivity	Conductivity	Corrosive Classification	Sub-class
4000	250	Moderately corrosive	Mo-1
2000	500		Mo-2
1000	1000	Corrosive	C-1
500	2000		C-2
250	4000	Severely corrosive	S-1
			S-2

the curves it is easy to calculate the standard deviation from the logarithms of the resistivities at certain probabilities. For example, it is known from statistical analysis that 68.27 percent of the probability under the normal probability density curve lies within the range from minus 1 to plus 1 standard deviations, and that 95.45 percent lies in the two sigma range and 99.73 percent in the three sigma range. Therefore, to estimate the standard deviation, one should find the logarithm of two resistivities associated with probabilities corresponding to certain integral standard deviations and divide by the number of standard deviations. The probabilities associated with the several multiples of the standard deviations are shown in Table 2 in which are also given the resistivities (and their logarithms) which were interpolated from the curve of Figure 2. At the bottom of Table 2 the data are characterized as suggested earlier in the paper. Note that in the second equivalent expression the resistivity rather than its logarithm is given and that the standard deviation is now a ratio by which the mean must be multiplied or divided to find the resistivity corresponding to a given abscissa in terms of standard deviation. The mean resistivity of a sample is the  $n$ th root of the product of the  $n$  measurements.

Consider the use of galvanic anodes on a pipeline. The soil is sampled by resistivity measurements and data obtained similar to those displayed in Figure 2. It is known from experience and from theory that the current discharged from a magnesium anode can within reasonable limits be calculated by the equation:

$$I = 184/\rho = 0.184k$$

where  $\rho$  is the soil resistivity in ohm-centimeter and  $k$  the conductivity in millimho per centimeter. For a 17-pound anode the life in years at 50 percent efficiency is given by the reciprocal or:

$$L = \rho/184$$

Thus, if any number of magnesium anodes were installed in the area represented by a curve similar to Figure 2, it would be possible to estimate the individual and total current output of the anodes according to the first equation. The life of each anode could be estimated according to the second equation. The maximum or minimum current output or anode life, and the percentage of decayed anodes at any given time can be estimated from these equations. Two ordinates may be labeled in which current discharged and anode life would replace resistivity as the logarithmic ordinate.

In Figure 5 are shown 104 soil resistivity measurements plotted as a probability distribution. The data were taken for the author in Central Texas with



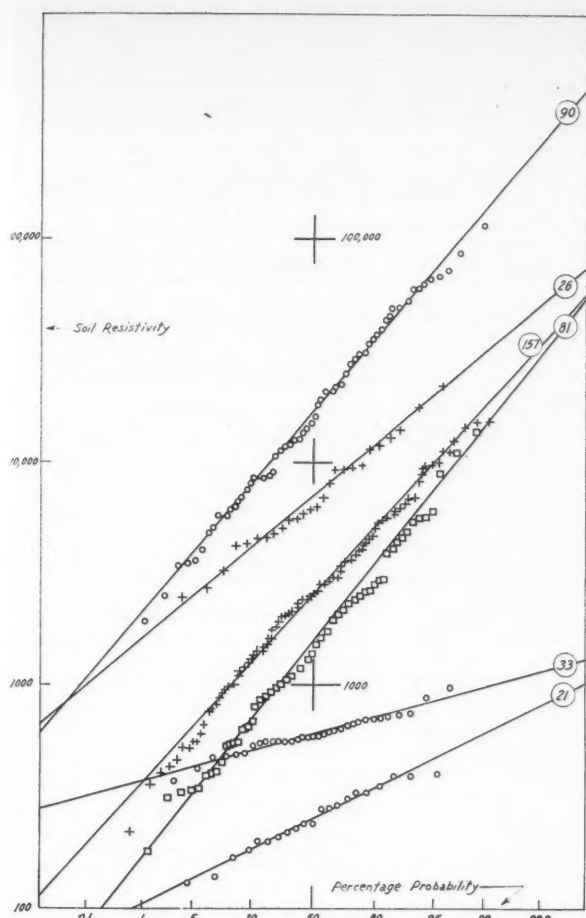


Figure 4—These six sets of data from widely scattered locations illustrate variations in means and slopes of uniform soils.

a Miller instrument. The experimental points are shown as small circles. An arrow points to the geometric mean—the median—where the resistivity is 1620 ohm-centimeters. Shown on the curve are nine circles, four of which are shaded. The pipeline was inspected at ten locations and the observer, unskilled in corrosion investigations, characterized the condition of metal found as "normal" corrosion represented by the clear circles and "severe" corrosion shown by the shaded circles. The soil resistivity as shown in the figure was nearly the same at two locations showing severe corrosion. Therefore there are only four shaded circles instead of five. An advantage of the probability distribution method of displaying the data is that use can be made of such qualitative corrosion information.

These 10 inspections shown in the chart indicate that corrosion is related to soil resistivity. This relation was also indicated in Figure 3, where the four leaks occurred in the range of the lower resistivity soils. Thus a new approach is possible in the study of underground corrosion data.

This 11-mile long pipeline gave rise to an interesting speculation. At one location where a leak had occurred, the joint (i.e., the junction between lengths of pipe) was found to be uncoated and thus defective. The question then arose as to whether it would be profitable to

expose all of the many joints for examination and repair. But from the figure it is evident that the soil resistivity at a probability of 1/2000—the reciprocal of the approximate number of joints—would be about 180 ohm-centimeters. The point is shown as a circled cross in the figure. If all of the joints were defective, it would be reasonable to expect to find many leaks in soils of such low resistivity, whereas actually the resistivity at which the one leak did occur was greater than 500. Accordingly, it would not be profitable, "in all probability," to inspect all of the joints since it is most likely on the basis of this reasoning that only a few of the joints were actually defective.

Similar reasoning applies to many other questions which may be asked. For example, if a soil is fairly corrosive, the chance of a single holiday in a pipe coating falling in the most corrosive region of the soil is indeed a remote one, whereas, if there were a thousand holidays in the coating, it is probable that a hole in the coating would coincide with a low resistivity soil. If the soil parameters were known it would be pos-

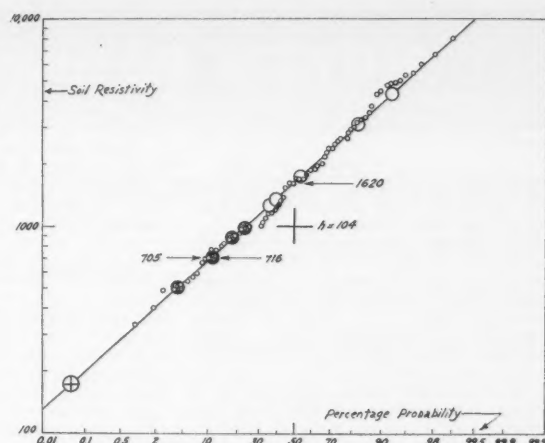


Figure 5—The corrosion was severe at locations corresponding to the large dark circles and moderate or absent at white circles. The circled cross indicates the lowest resistivity which would be expected if the sample size were 2000 instead of 104.

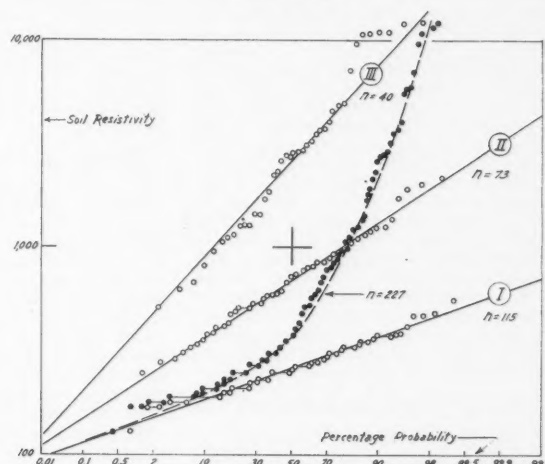


Figure 6—The 228 soil resistivity measurements shown by the black dots do not conform to a normal distribution but the three groups derived from them with the aid of a plot of conductivity against pipeline stationing conform to straight lines.

sible to specify what minimum soil resistivity would likely be associated with any given number of holidays. Thus it might prove advisable to inspect the coating with a holiday detector or to use asphalt-mastic pipe coatings according to the soil parameters. In the asphalt-mastic coatings a holiday might occur in every two or three-mile interval in comparison to hundreds of holidays per mile in very poor coatings.

The illustrated method of characterizing soils serves to distinguish them with respect to resistivity or to the related corrosive quality. In Table 4 are the soil parameters for a pipeline which originates as a 6-inch line at a gas compressor plant at Church Buttes, becomes an 8-inch at Baxter Basin Junction and terminates at Intermountain Chemical Company's soda ash plant at Westvaco, Wyoming. Water is brought to the plant from the Green River. These three pipelines are each nearly ten miles in length and are in line in a more or less continuous right-of-way. The table shows that the soils for the two gas lines are the same with respect to mean resistivity and standard deviation and

TABLE 4—Soil Parameters for Pipe Line\*

6-inch Gas Pipeline: . . .	N(109, log $\rho$ ; 1700, 1.869)
8-inch Gas Pipeline: . . .	N(86, log $\rho$ ; 1600, 1.876)
10,12-inch Water Pipeline: . . .	N(73, log $\rho$ ; 3650, 2.8222)

\* Intermountain Chemical Company Westvaco, Wyoming.

thus to corrosive quality but are quite different from those along the right-of-way of the water pipeline.

As a further graphic example, which also serves to show that not all data perform ideally as would be indicated in the curves so far presented, data for a water pipeline of the Reynolds Metals Company near Corpus Christi, Texas, have been plotted in Figure 6. The parent data in skeleton form are shown by the small shaded circles and the three distinct soil groups, derived from the parent curve, are separately plotted.

If the electro-chemical theory of corrosion is applicable to a buried pipeline and if Ohm's law is obeyed, then at constant galvanic voltage a linear relation between corrosion rate and soil conductivity must of necessity follow "on the average." Corrosion is proportional to the total current  $I$  which is inversely proportional to resistivity  $\rho$  and directly proportional to conductivity  $k$ . Thus  $I = E/R = E/\rho f(g) = Ek/f(g)$  where  $f(g)$  is a purely geometrical factor. Accordingly, if soils are to be studied with respect to corrosion, the conductivity should be plotted with respect to stationings along the pipeline or over an area and not the resistivity itself nor its logarithm. This plot puts the resistivity measurements in better perspective with respect to corrosivity. The data in Figure 6 were easily separated visually into three groups by plotting conductivities against the pipeline stationings. The three uniform soils separated in this way are characterized as follows:

Group I: N(115, log  $\rho$ ; 260, 1.309)

Group II: N(73, log  $\rho$ ; 750, 1.653)

Group III: N(40, log  $\rho$ ; 2850, 2.461)

Figure 6 suggests that the three soils developed from a common source since the curves appear to radiate from a common resistivity. The knowledge that the logarithms of resistivity in a uniform soil are normally distributed thus provides a valuable research tool.

The above discussion assumes the galvanic voltage  $E$  to be constant in a uniform soil. The influence of this variate and its distribution upon soil corrosion will be discussed in a forthcoming paper.

In the author's New York paper,<sup>1</sup> it was necessary for the theory presented to find the distribution of the extreme values of soil resistivity as a function of sample size. The problem was simplified by the fact that the log-resistivity distribution was normal, since the distribution of the extremes of a normal distribution for samples of size  $n$  are now well known (see Gumbel). Without the discovery discussed in this paper, however, the theory presented by the author could not have been so successfully developed.

It was also shown in the author's New York paper that the total corrosion was proportional to the square root of the time the metal is buried. With this additional information it is possible to make efficient use of few inspections, for example, of H-piles under buildings. By the methods discussed in previous paragraphs, the data can be extrapolated if the soils conform to a normal distribution or can be segregated into soils which do conform to normal distributions, so that the worst probable condition can be determined and speculations made regarding what that condition would be years hence. A problem of this type on such bearing piles is within the author's experience. The cost of inspecting many bearing piles beneath buildings is prohibitive. The methods discussed herein are thus invaluable in arriving at solutions from few data, of problems of considerable economic importance.

The author's long-range objective outlined in the New York paper is to account for the rate of development of leaks

on pipelines in relation to the soils through which the pipelines pass. This objective is easily within reach and awaits experimental determination of the linkage between soil conductivity and cumulative pipeline leaks.

A recent statistical analysis made from pipeline records by a large gas company showed that it was not most economical to apply cathodic protection as soon as a pipeline was laid. This fact has long been known and advocated by the author. This company used in the absence of other data, the time to the first leak as the criterion for economic comparison. Since the time of first and subsequent leaks are a function of soil conductivity, the methods here disclosed by the author should apply to the problem.

### Conclusion

The data presented show conclusively that soils in a very large number of cases exhibit conductivities whose logarithms are normally distributed. This important discovery opens a new field for investigation for corrosion engineers and makes possible better engineering in soil corrosion mitigation.

### Acknowledgment

The author acknowledges with gratitude the privilege afforded by all of the organizations named of using the data and disclosing their source.

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3. Frank Wenner. *Bull. Bu. of Stds.*, 12, No. 3, 469 (1916).
4. Keuffel & Esser Company. *Probability X Logarithmic (2 Cycles)*, 359-23.
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Any discussions of this article not published above will appear in the December, 1958 issue



## TECHNICAL COMMITTEE ACTIVITIES

# Even Small Amount of Hydrogen Sulfide Damaging

## Probe Is Underway On Domestic Hot Water Tank Corrosion

Various problems concerning corrosion of tanks was the principal subject considered by Unit Committee T-4E on Corrosion by Domestic Waters at a March 18 meeting in San Francisco.

R. C. West told members present he is completing a questionnaire on corrosion of hot water tanks. Little work has been done on this problem, he said. Plans are to use persons expert in corrosion for obtaining data. L. C. Wasson, C. W. Ambler, A. O. Smith and R. H. Gieser expressed interest in helping Mr. West.

General information concerning tanks brought out several points. Vents on top of a tank have been designed to discharge  $O_2$  and  $CO_2$  but prevent escape of water. These are said to reduce corrosion.

Use of epoxy coatings on tanks used in schools was discussed. Some details in surface preparation and the number of coats used were given. Deterioration of glass linings of tanks where copper tubing enters was brought up. Putting a trap full of zinc between the copper pipe and the tank was suggested as a solution to this latter problem. Other problems related to use of glass lined tanks were considered.

Concerning cathodic protection requirements of domestic hot water tanks, it was mentioned that Case Institute of Applied Science, Cleveland is working on the problem.

Oxygen removal by reaction with monatomic hydrogen under controlled cathodic protection was described by one of those present.

It also was pointed out that an increase of temperature markedly accelerates corrosion of plain mild steel. It was asserted that from 160 to 180 F the corrosion rate increases by a factor of 2.6 and that this effect is worse in ion-exchange (softened) water than in natural water. Questions concerning use of cement linings and rubber-cement lining composition were asked.

The program on testing of short lengths of pipe in different areas was discussed. Tests have not been in progress long enough to provide data.

## Preliminary Report Given On High Pressure Wells

A preliminary report of an important questionnaire circulated by Task Group T-1B-1 on High Pressure Well Completion and Corrosion Mitigation Procedure and a report on batch treatment of high volume gas wells were principal

(Continued on Page 66)

## 33 Technical Committees To Meet During Fall

Meetings of 33 technical committees are scheduled for three of the five regional meetings to be held this fall. They are as follows:

Northeast Region; Oct. 5-8, Boston: T-3G-1, T-4F-1, T-5A-5, T-2K.

North Central Region, October 15-17, Cincinnati: Wednesday, Oct. 15—Morning, T-5B, T-3F; afternoon, T-6F, T-2K; Thursday, Oct. 16—Morning, T-7B, T-5A-4; afternoon, T-5A-6.

South Central Region, October 20-24, New Orleans: T-1—B, C, D, F, H, J, K, M; T-2—D, J, K; T-3—D-1, T-5C-1; T-6A, T-6A-17, T-6B and D; T-8, T-8A.

## Surface Preparation Units Discuss Six Subjects

Unit Committees T-6G on Surface Preparation for Organic Coatings, and T-6R on Protective Coatings Research held a joint meeting in San Francisco, March 17, during the NACE 14th Annual Conference.

Formal business of the committees was dispensed with, and an informal symposium was held to present new developments and progress in coatings research. The six subjects for the symposium were: Anchor Pattern Standards, by E. W. Oakes, Clemtex, Ltd.; Minimum Paint Thickness for Economical Protection—a Progress Report, by G. Schurr, Sherwin-Williams Co.; Painting of Rusty Steel—Progress Report, by John Keane, Steel Structures Painting Council; AWS Metallizing Test—Progress Report, by C. P. Larabee, U. S. Steel Corp.; Painting of Welds, by John Keane; and Surface Treatment for Vinyl Coated Steel, by Joseph Bigos, U. S. Steel Corp.

On Anchor Pattern Standards, Mr. Oakes told of work done leading toward anchor pattern standards related to specific abrasive materials which are available locally in Texas. Considerable discussion developed from his presentation.

### Three Sites Are Used

The presentation of Minimum Paint Thickness for Economical Protection discussed project difficulties in exposing mild steel specimens for rusting, then preparing and coating the specimens. The project was activated in 1956 at the North Dakota college by the Federation of Paint & Varnish Production Clubs. Exposure sites include Kure Beach, N. C. for marine exposure, Detroit for industrial exposure and Fargo, N. D. for rural exposure. The current status report was given briefly. Committee T-6R is cooperating in the pro-

(Continued on Page 68)

## Some Chromium Tubing Failures Reported from Carbon Dioxide, Sulfur

Two papers presented in the Oil and Gas Production Symposium at the 14th NACE Conference stimulated considerable interest at the meeting of Unit Committee T-1F on Metallurgy held March 20, 1958, during the conference. The papers were, Laboratory and Field Methods for Quantitative Study of Sulfide Corrosion Cracking, and Influence of Metallurgical Variables on Resistance of Steels to Sulfide Corrosion Cracking. Authors of the first paper were J. P. Fraser, G. G. Eldredge and R. S. Treseder, Shell Development Co. Mr. Fraser and Mr. Eldredge were authors of the second.

At the meeting of Task Group T-1F-1 on Sulfide Stress Corrosion Cracking, J. E. Landers, Continental Oil Co., presented a report on stress cracking studies which indicated cracking of 9 chrome and 4340 tubing may be associated with very small quantities of hydrogen sulfide in what might normally be considered sweet condensate wells.

### Minimum Quantity Tests Made

Mr. Fraser told the group sulfide stress cracking tests are being conducted to determine the minimum quantity of hydrogen sulfide to cause cracking. Tests indicate a decrease in probability of failure with a decreased in hydrogen sulfide concentration.

One member told of cracking failures in joints in hard nine percent chromium tubing in gas wells containing a large volume of  $CO_2$  with approximately 0.2 grains of sulfur as mercaptans and no hydrogen sulfide. Small amounts of various poisons including hydrogen sulfide and mercaptans promote hydrogen absorption, which in turn causes sulfide stress cracking, one member said.

Some doubt was expressed concerning the hydrogen theory as the complete explanation of sulfide stress cracking. In connection with the role of hydrogen, the opinion was advanced that hydrogen could enter steel on the compression side and cause failure on the tension side and that there is a critical amount of hydrogen necessary to cause cracking.

In answer to the question whether shot peening would change the tendency toward cracking, one person present believed if shot peening was uniform, very high tension forces could be applied without cracking. Another said peened surfaces showed higher rates of corrosion on weight loss tests although, it was pointed out that this might be because surface area of shot peened materials was greater.

Also brought up in the T-1F-1 meeting were results of an experiment in which a plot of electrode potential as a function

(Continued on Page 66)



## Even Small—

(Continued From Page 65)

of location and time of failure suggested an electro-chemical effect in sulfide stress cracking. It was brought out that a technique had been developed to measure the rate of hydrogen penetration into steel. Suggestions were asked as to how this tool could be used in studying the role of hydrogen in stress cracking.

Following the T-1F-1 meeting, Task Group T-1F-2 on Sweet Crude and Sweet Condensate Stress Corrosion Cracking met with Mr. Fraser as chairman. He reported that information

available through two years of study indicated there is some trouble from this cause in service but that it is difficult to reproduce in the laboratory. He asked anyone with information to send it to him.

### Better Materials Control Sought

The need to control properties of higher strength materials was pointed out. It was said that eventually it will be desirable to define well conditions precisely in material applications.

Circumferential failures in slip marks associated with notch sensitivity in P-105 and P-110 drill pipe was also mentioned. Concerning the problem of time delay failures encountered in shut-

in wells, the opinion was given that this may involve a mechanism not previously considered.

Following adjournment of T-1F-2, Unit Committee T-1F considered other matters on its agenda. These were: Shot-peening of sucker rod surfaces, status of alternate rod mixed string tests (sucker rods), case hardened sucker rod couplings, materials for high temperature (thermal recovery) production, full length normalizing of upset tubing, API committee on corrosion fatigue testing, external corrosion of small "macaroni" tubing clamped to larger tubing in three string hydraulic pump operations, external corrosion of couplings on power oil tubing strings in hydraulic pump operations, welding accessories to high strength casing, and new API and other high strength steels—corrosion and cracking considerations.

## Preliminary Report—

(Continued From Page 65)

features of the meeting of Unit Committee T-1B on Condensate Well Corrosion. The Committee met March 19, 1958 during the NACE 14th Annual Conference in San Francisco.

The batch treatment report was made by Jack L. Battle, Humble Oil and Refining Co. Purposes of the field test on inhibitors were to evaluate the following variables: 1. Type of inhibitor. 2. Amount of treatment. 3. Length of shut-in time following treatment. 4. Persistence of the inhibitor. 5. Effect of rate of flow on results.

Tests were run on 29 gas wells, producing an average of 10-15 million cubic feet per day per well through 2-inch and 2½-inch tubing from 11,500-12,500-foot depths.

To start the test, four gas wells were left untreated for four weeks. Iron contents rose to 90 parts per million. But this was far below the 150 parts per million existing in all wells before any original treatment had been made.

In the first treatment to determine the effect of shut-in time, it was shown that very good results were obtained by a 24-hour shut-in as compared to a shut-in time of only four hours.

In the second test, the amount of inhibitor was doubled. The well shut-in for 24 hours received much more and longer lasting protection than the one shut-in only four hours.

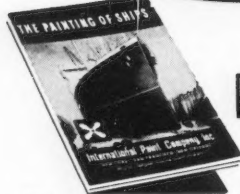
In the third test, an inhibitor with 30 percent active ingredients was compared to one with 90 percent active ingredients. By using twice the volume of the less concentrated inhibitor, equally good results were obtained. There was a six-to-one price advantage in using the less concentrated inhibitor.

The final tests were run to more clearly evaluate the effect of shut-in time on the results of treatment. Shut-in times were for eight, twelve, sixteen and twenty-four hours. Data derived from the test indicated eight hours as a minimum for obtaining satisfactory corrosion control in the field.

A detailed summary of results from the T-1B-1 questionnaire on High Pressure Well Corrosion Control was presented. The report summarized a great number of facts acquired from the questionnaire. Interest in the report was high and D. R. Fincher, T-1B chairman said the project was perhaps the most important concern of the committee.



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## High Purity Water Bibliography Underway

Compilation of an annotated bibliography on corrosion products in high purity water is being undertaken by Task Group T-3F-3 on Corrosion Products. The task group is part of Unit Committee T-3F on Corrosion by High Purity Water. Compilation of the bibliography was decided upon at the meeting of Committee T-3F in San Francisco, March 18, 1958.

Other subjects presented at the meeting included how far the committee should extend its interests in the discussion of inhibitors. The question of inhibitors for stress corrosion cracking and for corrosion and pit formation during steam generation were raised. A letter report from E. P. Partridge, in charge of inter-committee activities commented on the activities of an ASME committee on Boiler Feedwater studies and the work of a committee of ASTM on Industrial Water.

Chairman R. U. Blaser suggested the field of radiation effects might be considered by the committee. Next meeting of the committee will be at the North Central Region Conference, Cincinnati, October 15-17, 1958.

Concerning the annotated bibliography, W. L. Pearl, chairman of T-3F-3 pointed out that data on the quantity of corrosion products generated is needed for design purposes. R. U. Blaser indicated that data regarding such items as the pounds of copper, iron and other materials entering steam generating systems is needed on a per day basis.

S. L. Williams said the Naval Reac-

tors Program is now initiating schemes for obtaining reliable corrosion product release rates. W. K. Boyd reported he makes a quarterly review including material on corrosion products and would be glad to select pertinent material to be incorporated. M. C. Bloom said a current bibliography of information dealing with corrosion products in the Fe-O-H<sub>2</sub>O is being kept at the Naval Research Laboratory from which he volunteered to select pertinent material. Chairman Blaser suggested contacting NACE abstractors and the Edison Electric Institute to help in the work.

In the letter report from Mr. Partridge, it was indicated that the Joint Research Committee on Boiler Feedwater Studies, an ASME group, has been trying for several years to initiate a program of research on the reaction of boiler water with boiler steel at elevated temperatures. The report also indicated that the ASTM group's work involved setting up tentative specifications for reagent water under ASTM Designation D-1193 and standardization of several methods of test in connection with the use of pure water; two examples of classification were cited: D-888, Dissolved Oxygen in Industrial Water, and D-1068, Iron in Industrial Water.

Mr. Pearl presented a draft of a letter to be sent to committee members concerning the annotated bibliography.

## Surface Preparation—

(Continued From Page 65)

ject and further progress reports will be presented at future meetings.

The progress report on the Painting of Rusting Steel was given by Joseph

Bigos. Rust was substituted for iron oxide portions of paint formulations in whole and in part. Results of exposure tests so far shows that the presence of rust in paint formulations apparently does not promote failure of paint products. Work is continuing on the project.

Objectives, specimen information and exposure sites were discussed in the progress report on the AWS Metallizing Test. Interim results were presented.

## Weld Painting to Be Analyzed

In another interim report on the Painting of Welds, information was given concerning specimen preparation, materials used and raw results. Statistical analyses will be used to arrive at final conclusions.

Discussion of Surface Treatment for Vinyl Coated Steel concerned a production method of applying vinyl coatings to strip steel. Problems involved in application of an adhesive coating to cold rolled steel to permit later application of vinyl plastisol for production forming and drawing in fabrication were presented. Improving adhesion by chemical treatment of the steel surfaces and choice of a selective adhesive coat compatible with the vinyl plastisol finishing coats were discussed.

Next meeting of Committee T-6R will be held at the NACE 15th Annual Conference in Chicago.

## Leakage Conductance Officers Are Elected

L. F. Heverly, Trans-Canada Pipe Lines Ltd., Toronto and E. Allen, Jr., Humble Pipe Line Co., Houston have been elected chairman and vice chairman respectively of Unit Committee T-2D on Standardization of Procedures



Heverly



Allen

for Measuring Pipe Coating Leakage Conductance. Marshall E. Parker, former chairman, resigned his post and the election followed.

At the committee's March 18 meeting in San Francisco, L. A. Hugo, W. E. Huddleston and F. H. Rogers were selected as a task group to report on methods for coating conductance tests in the special case of paralled lines. A discussion of different types of suggested exemplary tests to be made on Great Lakes Pipe Line Co. lines followed.

One member suggested to the committee it incorporate diagrams that would show pictorially the procedural set-up for measuring coating conductance. Another member volunteered to submit data to the committee to show that the procedure as now presented can be improved.



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## NACE NEWS



SAN JOAQUIN SECTION members are shown inspecting some of the exhibit specimens which will be shown during the section's September 24-25 Guided Corrosion Tour. Examining the corroded anodes, oil well packer, casing, tubing and other items are, left to right, Jerry P. Mitchell, Norcor Chemical Co., tour chairman; Herbert E. Rose, Superior Oil Co., vice-chairman; Robert L. Davis, Superior Oil Co., section chairman, all of Bakersfield.

### Baton Rouge Area Section Approved

Greater Baton Rouge Area Section has been approved as a section of NACE by officials of the South Central Region and a request that a charter be granted the section has been made. Approval of the section's rules and regulations was dated June 30, 1958.

Officers of the Greater Baton Rouge Area Section are: Paul E. Weaver, Dow Chemical Co., Louisiana Div., chairman; Arthur H. Tuthill, Valco Engineering Inc., vice-chairman; Donald C. Townsend, Ethyl Corp., secretary-treasurer; and Robert M. Eells, Esso Standard Oil Co., trustee.

The next to last Monday of each month has been selected as the meeting date for the section and the Bellemont Motor Hotel has been chosen as the permanent meeting place. Scheduled for the June 23 meeting was a talk on clad metal for the chemical and petroleum industry by Louis Kaey of Lukens Steel Co.

### Panhandle Section Elects Edminster as Chairman

Newly elected officers for the Panhandle Section were announced at the May meeting. New officers are: J. W. Edminster, Cabot Carbon Co., Pampa, chairman; S. A. Evans, J. M. Huber Corp., Borger, vice chairman; W. A. Tinker, Phillips Petroleum Co., Phillips, Tex., secretary-treasurer.

Jack R. St. Clair, Dearborn Chemical Co., Whitdeer will serve a second year as trustee. The section meets on the last Tuesday of each month from September through November and from January through May. Meetings are held in Borger and the section welcomes visitors.

### SINGLE COPY PRICES OF CORROSION INCREASED

Effective at once the price of single copies of CORROSION to members of the National Association of Corrosion Engineers will be \$1 each. The price of single copies to non-members of NACE will be \$2 each.

For issues dated two or more years past (i.e. all issues dated 1956 or earlier) the price per copy is \$2 to members and non-members alike.

### Southeast Region to Meet in Richmond

Richmond, Virginia has been selected as the site for the 1958 fall meeting of Southeast Region. The October 6-7 meeting, to be held at Hotel Jefferson, will focus on the theme: Latest Methods and New Theories in Corrosion Mitigation.

Robert D. Williams, Charlotte, N. C. is general program chairman and George R. Lufsey, Virginia Electric and Power Co., Richmond, is local arrangements chairman.

### No NACE Yearbook to Be Published in 1958

No yearbook will be published by NACE in 1958. Persons who bought copies of the 1957 Yearbook will be sent free of charge a copy of a 1958 revised directory of technical committees if they ask for it.

Those interested should address their requests to J. F. Vander Henst, Technical Committee Secretary at Central Office.

### Six Exhibits Have Been Arranged for San Joaquin Tour

Exhibits have been arranged at establishments of six of the major oil companies operating in California for inspection during the San Joaquin Valley Guided Corrosion Tour. The tour, sponsored by San Joaquin Section, will be held September 24-25 in the vicinity of Bakersfield, Cal. Actual field inspection of equipment and subsequent discussions of corrosion control measures will be featured.

Jerry P. Mitchell, Norcor Chemical Co., Bakersfield, general tour chairman, said a collection of supplementary exhibits, including corroded tubing, anodes and other oilfield equipment is being assembled also. Interest in the tour is running high in the San Joaquin Valley and Los Angeles Basin. Registration announcements were mailed from Bakersfield July 14 and any person who did not receive an announcement may get one by writing to Mr. Mitchell.

The schedule for the tour has been outlined as follows:

#### September 24

8-11 am—Registration and tour briefing. Bakersfield Inn, headquarters.

12-5 pm—Tour.

7 pm—Panel discussion.

#### September 25

8 am-5 pm—Tour.

6 pm—Social hour.

7 pm—Luau dinner.

Preliminary approval for exhibits has been arranged with the following companies: Superior Oil Co., Standard Oil Co., Honolulu Oil Co., Ohio Oil Co., Richfield Oil Co., Western Gulf Oil Co.

### New York Section Sets Four More 1958 Programs

Technical programs for section meetings of the Metropolitan New York Section for the remainder of the year have been set, according to A. F. Minor, vice-chairman. The program follows:

Comparative Corrosion Resistance of Titanium and Other Metals by F. W. Fink, Battelle Memorial Institute, Columbus, Ohio, September 17.

Underground Corrosion by Microbiological Action, by F. E. Kulman, Consolidated Edison Company of New York, New York, October 15.

Marine Corrosion—Panel Discussion; moderator, Frank J. McGinity, Charles Engelhard Co., East Newark, N. J., November 12.

Corrosion of Iron and Steel, by C. P. Larrabee, United States Steel Corp., Monroeville, Pa., December 10.

### Baltimore Chosen for 1959

The Lord Baltimore Hotel, Baltimore, Md. will be headquarters for the October 5-7, 1959 meeting of Northeast Region.

## From the Desk of Your EXECUTIVE SECRETARY

T. J. Hull, Executive Secretary

• **Oil and Gas Well Corrosion Manual**  
A special editorial committee of T-1 has completed a 50-page Manual on Corrosion of Oil and Gas Well Equipment. The manual is a comprehensive guide to corrosion problems and techniques of mitigation practices in the oil and gas producing industry. While it is aimed at field and operating personnel below the corrosion engineering level it also can be used to give management a quick introduction to corrosion problems and what their engineering departments are doing to mitigate them. Three years' work went into the manual, which was initiated at the request of the American

Petroleum Institute Division of Production. It will be published and sold by the API. Although NACE was given the opportunity to participate in the sale of the manual your very economic minded Executive Committee decided that the major profit will come from acknowledgement that the manual was written by NACE.

### • High Pressure Well Research

T-1K on Inhibitors for Oil & Gas Wells will soon submit a proposal to the Board asking authorization to initiate an industry-sponsored research project on methods of mitigating corrosion in high pressure wells with bottom-hole pressures of up to 15,000 psi. The committee has received a proposal from a research institution in Austin, Texas that appears to be reasonable and well-founded. The project will cost in the neighborhood of \$60,000, most of which already has been promised by the oil and gas producing industry.

### • Minimum Pipeline Requirements

The T-2 report on "Minimum Requirements for the Protection of Buried Pipe Lines" is nearing completion. Mr. Stewart has asked his unit chairmen to provide copies of completed recommendations for review at the committee meeting to be held in October.

### • Plastics Numbering System

A task group of T-5D under the chairmanship of Otto H. Fenner is working diligently on the NACE Plastics Number System. Technical committees of four other organizations have been invited to participate in the work. The system will be similar to that used for stainless steels and when completed and adopted by industry will assure the user that he is getting the plastic he orders. It will be a great aid in the design of plastics since it provides physical characteristics and chemical resistance information keyed to numerical designations.

### • Corporate Member Campaign

The contract with the public relations firm of Harry Krusz Company has been terminated. Briefly, the Executive Committee believes that Harry Krusz Company has accomplished what was originally intended for it to do, that is, to plan and assist in the organization of a corporate member program. The association's wide corporate member program, of course, will be maintained and efforts to gain new corporate members will be continued. However, emphasis is to be placed on planning special services to offer corporate members over and above those offered to active members. Immediate services under investigation include gratis copies of Bibliographic Surveys of Corrosion and a special publication. These services will be discussed in detail by the Publication Committee and reviewed by the Executive Committee at a meeting in October.

### • 15th Conference and 1959 Corrosion Show

Plans and arrangements for the 15th Annual Conference are well ahead of schedule. R. McFarland, Jr., Technical Program Chairman, and his symposia

chairmen have been very successful in obtaining papers for the technical program which while not complete, is nearing that point. Preprints of conference papers will be published by the association.

### • Displays of CORROSION

At the request of the U. S. Department of Commerce copies of CORROSION have been made available for display at U. S. Trade Fairs over the world. We also sent copies for display at Japanese book and periodical shows. This at no cost to the association.

### • Pipe Line Corrosion Film

The NACE film Technical Advisory Committee will meet in Houston on July 10 to review the final draft of the scripts for the films on Fundamentals and on Coatings. The preliminary draft of the script has been extensively revised by the small Review Committee of the Film Advisory Committee. The films are being produced by the Petroleum Extension Department of the University of Texas. NACE is acting as technical advisor only.

### • Change of Type Size Weighed

The Publication Committee is considering a change to a larger type for the Technical Section of CORROSION. It is estimated that a substantial saving has been realized this year so far in printing cost from the change to the present 3-column format and smaller type. The cost of cuts for the section is substantially less also. The per copy cost of printing CORROSION for the first six months of the year increased 4c more than was estimated last November.

### • NACE Headquarters Building

The Executive Committee has asked W. H. Stewart and R. A. Brannon to work with your executive secretary and treasurer to investigate the possibility of purchasing property and constructing a building to house Central Office. The association is now paying almost \$10,000 annual rent for offices in the M & M Building. The Executive Committee is of the opinion that it may be more economical in the long run to build a Central Office than to continue paying high rent.

## San Diego's Annual Social Meeting Attended by 87

San Diego Section held its annual social meeting May 21. The meeting provided an opportunity for 87 members and their wives to become better acquainted. They heard Harvey Ellsworth, Convair Astronautics, discuss the Atlas test vehicle and its future use. The meeting was held at the Town and Country Hotel, San Diego.

Next scheduled meeting of the section is September 17 when the program will consist of four short discussions of home problems of corrosion, starting with piping to the house, inside the house and methods of detection and correction. Four speakers will be on the program.

## Houston Section Meetings

Houston Section has changed its meeting place to the Houston Engineering and Scientific Society, 2621 Fannin. W. A. Wood, Jr., Products Research Service, Inc., section chairman made the arrangements with the Engineers' Club to use its recently remodeled facilities.



## TECHNICAL REPORTS

on

### CORROSION PROBLEMS in the PROCESS INDUSTRIES

TP-5A Materials of Construction for Handling Sulfuric Acid. Corrosion, August, 1951, issue. \$2. Per Copy.

T-5A-3 Corrosion by Acetic Acid—A Report of NACE Task Group T-5A-3 On Corrosion by Acetic Acid. Pub. 57-25, Per Copy \$.50.

T-5A-4 A Bibliography on Corrosion by Chlorine. A Report of Technical Unit Committee T-5A on Corrosion in the Chemical Manufacturing Industry. (Compiled by Task Group T-5A-4 on Chlorine.) Pub. 56-2, Per Copy \$1.50.

T-5A-5 Corrosion by Nitric Acid. A Progress Report by NACE Task Group T-5A-5 on Nitric Acid. Per Copy \$.50.

T-5A-5 Aluminum vs Fuming Nitric Acids. A Report by NACE Task Group T-5A-5 on Corrosion by Nitric Acids. Per Copy \$.50.

T-5B High Temperature Corrosion Data. A Compilation by NACE Technical Unit Committee T-5B on High Temperature Corrosion. Pub. 55-6. Per Copy \$.50.

T-5C-1 Some Economic Data on Chemical Treatment of Gulf Coast Cooling Waters. A Report of the Recirculating Cooling Water Sub-Committee of NACE Task Group T-5C-1 on Corrosion by Cooling Waters, South Central Region. Per Copy \$.50.

T-5C-1 Water Utilization and Treatment Efficiency of Gulf Coast Cooling Towers—A Report of the Recirculating Cooling Water Work Group of NACE Task Group T-5C-1 on Corrosion by Cooling Water (South Central Region) Pub. 57-20, Per Copy \$.50.

TP-5C Stress Corrosion Cracking in Alkaline Solutions. Pub. 51-3. Per Copy \$.50.

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65c per package to the price given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

## NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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## Alabama Corrosion Short Course Aim of Birmingham Section

Possibility of establishing a corrosion short course in Alabama "so that it won't be necessary to travel hundreds of miles to attend a short course" was the principal topic discussed at the business session of the second quarterly meeting of Birmingham Section.

Technical speaker for the meeting was Stewart H. Gates, Southern Bell Telephone and Telegraph Co., chairman of the Louisville, Ky. Electrolysis Technical Committee. He spoke to the group of the many benefits of the committee approach in solving mutual problems in underground corrosion.

In other meeting statements an appeal was made for help in promoting corporate membership in NACE. Quality of technical papers published in CORROSION was praised by W. W. Garrett, section chairman, who said value of the magazine was well worth the price of joining NACE. On the subject of the magazines, it was pointed out that the Birmingham Engineering Council had originated a publication, "Alabama Engineer." Section members capable of writing semi-technical articles on corrosion were urged to submit them to the magazine.

Ralph Cunningham, Steele and Associates, Inc., who is already on a committee to promote corporate membership in NACE, was appointed chairman of the newly formed committee to investigate establishing a corrosion short course. The course would be jointly sponsored by the section and an Alabama college.

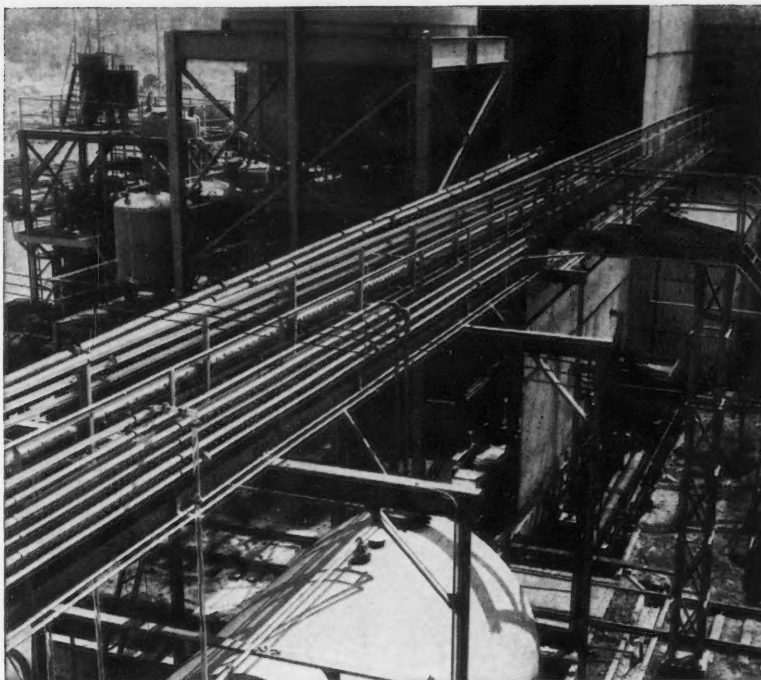
Casual discussion of such a course has already been held with the dean of engineering, Alabama Polytechnic Institute who appeared interested. Name's of a member of the faculty of Birmingham-Southern College and of one from Howard College were suggested as possible aids in forming such a school.

In his technical talk, Mr. Gates, who is the transmission and protection engineer for his firm in the state of Kentucky, said technical committees are particularly useful when a wide divergence of information is necessary to reach a sound conclusion; when the decision is of such importance that a "safe" judgment of several qualified individuals is desired; when successful execution of decisions depends on a full understanding of their ramifications; and where activities of three or more divisions need to be adjusted frequently to secure coordination.

Among eleven attributes of a good committeeman, he listed: A good understanding of corrosion, "corrosion consciousness;" a liking for his coordinates in the other utility companies and membership in NACE.

Some corrosion committees are highly organized with detailed written records being kept. Others require only an informal, friendly working group he said.

Next meeting of the section is to be held September 5. The subject will be Mississippi Valley Gas Company's experiences with deep sacrificial ground beds. It will be presented by Ralph Hurst, company corrosion engineer. R. W. Hicks will be program chairman for the meeting.



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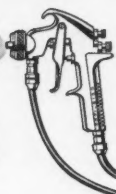
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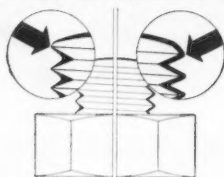
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## N A C E S T A F F



Clem



Foster



Schwarze



Wilson

The smooth operation of an office depends upon the efficiency of its secretarial help. Here are the members of the NACE Central Office secretarial staff.

Louise Bentley types many of the letters sent out by Central Office. She is a native of McDade, Texas, but moved to Madisonville where she graduated from high school. She also attended Massey Business College. Her hobbies are music, sports, TV and her home. She has been with NACE for more than five years.

Patricia Ann Clem is secretary to Frans Vander Henst, NACE technical secretary. In addition to other duties, "Pat" keeps up to date the technical committee files and the directory of technical committee officers which is printed in *CORROSION*. She graduated from Galena Park (Texas) high school and in addition, studied shorthand in night school.

Hazel Conyers is secretary to Norman Hamner, the managing editor of *CORROSION*. She also assists James Longino, technical editor. The records of *CORROSION* advertisers and the many details these records entail are in her charge. She keeps track of manuscripts in the exacting checking process each one goes through before it is published in *CORROSION*. She files photographic plates and photos, and handles correspondence for Mr. Hamner and Mr. Longino. She has been with NACE since 1952. After finishing high school she attended Egan's School of Fine Arts, Los Angeles. Her interests are music, English literature, fine arts and educational reading.

Willa Jean Foster is a comparative newcomer to NACE. She will help Gilbert Rolak, administrative assistant for regions and sections, and in addition will be available for other stenographic work. Willa Jean attended La Porte high school. A few days after graduating in June, 1957 she enrolled at Southwestern Business University. Strenuous sports

are among her hobbies; she likes water skiing, ice and roller skating, tennis, bowling and miniature golf.

Joyce Schwarze is secretary to R. W. Huff, NACE assistant executive secretary. In addition to the usual duties of a secretary, Miss Schwarze keeps contracts and records and compiles information on the important "Corrosion Show" NACE puts on each year in conjunction with the annual conference. After graduating from Houston's Reagan high school she attended Southwestern Business University. She will enter night school at the University of Houston in September where she will major in business administration. She likes sports of all kinds, boating, water skiing, and swimming.

Elaine Taylor as receptionist is an important contact between NACE and those who call on the association either by phone or in person. Elaine has done much of the detailed work involved in setting up records and following the progress of the NACE corporate member program. She is a native of Tenaha, Texas, where she attended high school. She then attended Southwestern Business School. Her hobbies are sports, church activities, American Legion, participation in Masonic organizations, VFW, Reserve Officers Association, and the Kentucky Colonel Club.

Claire Wilson keeps the records on *CORROSION* subscribers. From Carlisle, Mass., she attended Presentation of Mary Academy, Hudson, N. H. Her two children, Marguerite and Colette are her principal outside interests. She also attends plays and is active in the Delta Sigma Delta dental fraternity wives' club.

## Lehigh Valley Section Names New Officers

New officers and a new board of governors have been elected for the Lehigh Valley Section. This is the first time the section has elected a board of governors.

New officers are, Kenneth R. Cann, Ingersoll-Rand Co., Phillipsburg, N. J., chairman; L. H. Dale, Berwick, Pa., vice chairman; and Roger N. Longenecker, The Glidden Co., Reading, Pa., secretary-treasurer.

Elected as governors were, J. Byron Godshall, Ingersoll Rand Co., Easton, Pa., one-year term; John P. G. Beiswanger, General Aniline & Film Co., Easton, Pa., two-year term; and Edmund A. Anderson, New Jersey Zinc Co. of Pennsylvania, Palmerton, Pa., three-year term.

## D E A T H S

**Charles H. Bradford**, Garden Grove, Calif., affiliated with Barnes Delaney, Los Angeles, died April 15 of a heart attack. He was a member of NACE, was the NACE corporate member representative for his firm and had been associated with the company for 10 years. He was also active in API and the California Natural Gas Association. He is survived by his widow, Mary and daughter Karen.

South Central Region's 1961 Conference will be held October 24-27 at Houston's Shamrock Hotel.

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## SOUTH CENTRAL REGION BIOGRAPHIES

**ROY V. COMEAUX**—A native of White Castle, Louisiana. He graduated from Louisiana State University in 1939 with a BS in chemical engineering and has been an employee of Humble Oil & Refining Company since that time with the exception of four years spent in the Air Force during World War II. His major interests lie in the fields of cathodic protection, cooling water problems and the application of neutralizers and corrosion inhibitors to minimize aqueous corrosion problems.



Comeaux



Davis



Goodman



Miles

**GORDON O. DAVIS**—Graduated from Texas A&M with a BS Degree in electrical engineering. Began working for Transcontinental Gas Pipe Line Corporation June of 1958, as progress engineer during original construction. Remained in this capacity for three months and then spent the next five years in communications department as radio technician and later as communications engineer. The past three years have been spent in the corrosion department as corrosion engineer. Current duties are handling internal and external corrosion problems. He is a member of NACE, Associate Member of American Institute of Electrical Engineers and a registered professional engineer in the state of Texas.



Smith

**BARNARD P. GOODMAN** received his education at Baylor University, Waco, Texas completing his work there in 1951. Since that time he has completed further specialized studies in protective coatings chemistry at the University of Houston. Prior to his service at Tube-Kote, Inc., Mr. Goodman was employed by a Houston paint company in research and development of coatings for four years. For the last two years

(Continued on Page 76)

## SOUTH CENTRAL REGION ABSTRACTS

Development and Evaluation of deep ground beds, by Paul Miles, Corrosion Group Leader, Interstate Oil Pipe Line Company, Shreveport, La.

An economical method of applying cathodic protection to bare pipe lines in high resistance soil has been found. Interstate Oil Pipe Line Company is now using 250-foot vertical anodes with unusual success. This paper deals with the development, design, installation, performance and cost data of such groundbeds.

Sacrificial Anodes For Submerged Pipelines, by R. G. Ransom, Tennessee Gas Transmission Co., Houston.

System expansion into offshore areas for gas supply requirements presented hitherto unforeseen problems in regards to maintenance of a submerged pipeline.

Protective requirements for offshore sections

(Continued on Page 76)

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## Pipelines, Refining Topics at New Orleans

What is the best way to protect an undersea pipe line which cannot be reached once it is put down?

What is the performance in high resistance soil of cathodic protection of bare pipe using vertical anodes 250 feet deep?

These subjects are among those of papers to be presented in the Pipe Line Symposium at the South Central Region Conference and Exhibition, New Orleans, October 20-24, 1958. Experiences of top corrosion engineers in other industrial fields will be told in other symposia on oil and gas production, offshore corrosion and refinery and chemical process industries.

Tentative plans call for eight technical papers in the Oil and Gas Production Symposium, according to Jack L. Battle, symposium chairman. Titles of papers and their authors are:

Polyurethanes—Plastics with an Oil Field Promise, by B. P. Goodman, Tubekote, Inc., Houston.

The Testing of Tubing Coatings at Elevated Temperatures and Pressures, by G. J. Duesterberg, Plastic Applicators, Houston.

Results of Mixed Rod String Testing, by W. C. Koger, Cities Service Oil Co., Bartlesville, Okla.

Well Completion and Corrosion Control of High-Pressure Gas Wells (A Report of Test Committee T-1B-1), by W. F. Oxford, Jr., Sun Oil Co., Beaumont; E. H. Sullivan, United Gas Corp., Shreveport; and D. R. Fincher, Tidewater Oil Co., Houston.

Correlations of Oil-Soluble, Water Dispersible Inhibitors in Sweet Oil Systems, by C. C. Nathan, The Texas Co., Houston.

Laboratory Methods for Evaluating Corrosion Inhibitors for Secondary Recovery, by T. R. Newman, National Aluminate Corp., Chicago.

Field Evaluations of Cathodic Protection of Casing, by J. E. Landers, J. D. Sudbury, J. J. Lehman and W. D. Greathours, Continental Oil Co., Ponca City, Okla.

(A paper on ductile steel tubular goods for sour oil field service, a sequel to the paper presented in CORROSION, April 1957 by Cauchois, Didier and Herzog).

Approximately 26 technical papers will be presented in 211 four symposia. In addition to attending symposia, corrosion engineers will meet in technical committees to exchange information on their problems. Total attendance at some 20 meetings is expected to be a little less than 1500.

Abstracts, photographs and biographies of some of the authors are presented in this issue of CORROSION.



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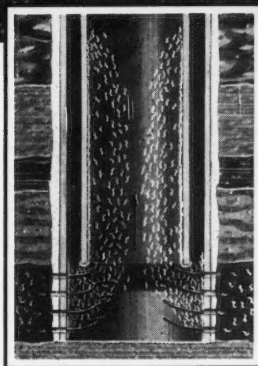
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## SOUTH CENTRAL REGION BIOGRAPHIES

(Continued From Page 74)

he has been Chief Chemist for Tube-Kote, Inc. in charge of and development of coating materials.

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**PAUL MILES** received his ME Degree from Louisiana Polytechnic Institute in 1949. After six years with a major gas transmission company, he was employed by Interstate Oil Pipe Line Company where he presently is serving as corrosion group leader. Mr. Miles is a registered professional engineer in Louisiana and Texas and a member of NACE and ASME.

**ROBERT G. RANSOM**—An electrical engineering graduate from Texas A. & M. College, he has been engaged in cathodic protection work for Tennessee Gas Transmission Company since 1951. His present duties include system design, installation, survey work and associated instrumentation. He is a member of NACE and AIEE.

**ROBERT E. SMITH**—Manager, vessel sales department of the Pfaudler Co., division of Pfaudler Permutit, has been with the firm since 1950. He has served in several capacities in production, staff and sales, assuming his present post, January 1958. He is author of an article on personnel selection published in the magazine, PERSONNEL. He is the originator of two patents which have been assigned to Defender Photo Supply, with which he was affiliated before joining Pfaudler. For three years he operated his own business making chemical specialties and food products. He is a graduate of Massachusetts Institute of Technology with a bachelor of science in chemical engineering.

## SOUTH CENTRAL REGION ABSTRACTS

(Continued From Page 74)

of the line remote from practical sources of impressed protective current and subject to irreparable coating damage during installation dictated use of a large amount of sacrificial anode material. Inaccessibility of the line after laying meant reliability and long life were paramount design factors.

Pipelining methods employed required no projections beyond the surface of the concrete weight coating and an essentially uniform line surface was necessary.

An anode design evolved consisting of a sleeve or bracelet of material replacing a portion of the weight coating on certain joints of pipe.

The bracelet of anode material consisted of anode sectors assembled into an annular ring about the pipe using a circumferential steel band at each end for support. Pipeline design with the working pressures involved prevented any direct welding of the assembly to the pipe itself.

Anode material requirements included resistance to passivity in seawater, good current efficiency, relatively low driving potential and molding considerations for the anode sector shape employed.

Because of the low electrical resistivity of the environment, current distribution aspect was

considered secondary to a standardized spacing for the pipelaying job. Then an anode length was determined to provide the necessary anode material for the protective requirements.

Experience gained with the completion of the first installation of 26-inch pipe has materially aided in the design of assemblies for subsequent pipeline installations of various diameters.

**Corrosion of Refinery Equipment by Aqueous Hydrogen Sulfide**, by R. V. Comeaux, Humble Oil and Refining Co., Baytown, Tex.

H<sub>2</sub>S corrosion problems at temperatures below 400 F in the presence of water are presented for a wide range of refinery equipment. The most commonly accepted solutions to the problems of corrosion and fouling are the use of resistant alloys and/or neutralization plus film-forming corrosion inhibitors. Experience at several units employing steel condenser tubes exposed to waters contaminated with H<sub>2</sub>S and other acids will be discussed. A theoretical study of the corrosion of steel in H<sub>2</sub>S solutions reveals that prevention of high velocity, low pH exposures should be an effective control measure. Analysis of several failures of steel-tubed exchangers are discussed in the light of additional improvements that may be possible in design and selection of materials. Preliminary tests indicate that zinc or aluminum coated steel tubes may be useful in this environment.

**Applications of Glassed Steel Equipment in Corrosive Service**, by R. E. Smith, The Pfaudler Co., A Div. of Pfaudler Permutit, Rochester, N. Y.

The corrosion resistance of glassed steel is discussed. Other properties of practical interest are reviewed briefly, including resistance to thermal and mechanical shock, absence of catalytic effects, anti-adhesion, cleanliness and reparability. A brief description of the manufacturing process is related to design considerations. Finally, an illustrated series of operating industrial installations of glassed steel equipment are presented as examples of the use of the foregoing properties.

## Booths Assigned For October Show In New Orleans

Companies whose contracts to exhibit at the South Central Region Conference have been received through July 14 have been assigned booth locations. The Conference will be held in New Orleans, October 20-24, 1958. While interest in the exhibition remains high, good booth locations are still available. Contracts for booth space may be secured from the Central Office of National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Tex.

Following is a list of booth numbers and companies holding space:

Company	Booth No.
Allen Cathodic Protection Co.....	17
S. E. Bosley Company.....	31
Wayne Broyles Engr. Corp.....	19
Carboline Company.....	21
Central Plastics Co.....	8
Corrosion Rectifying Company.....	10
John L. Dore' Company.....	3
Dowell, Inc. ....	7
The Duriron Company.....	24
Fibercast Company .....	30
Odis C. Galloway & Co., Inc.....	33
F. W. Gartner Company.....	23
Heil Process Equipment Corporation	16
F. H. Maloney Company.....	1
Metallizing Engineering Co., Inc.....	12
Chas. Pfizer & Co., Inc.....	22
Pittsburgh Coke & Chemical Co.....	36
Resistoflex Corporation.....	38
Rio Engineering Company.....	14
The D. E. Stearns Company.....	4
Texsteam Corporation.....	39
Valdura Div., American Marietta Co.	9
Visco Products Company.....	25
T. D. Williamson, Inc.....	37

NACE has published more than 75 reports of technical committees since 1950.

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# ACP ALODINE\* — its properties and functions in protecting aluminum alloys and bonding paint to them

By ALFRED DOUTY: Technical Director, AMCHEM PRODUCTS, INC.

Aluminum protects itself against corrosion by a coating of its own oxide. This adds weight, but does not provide complete protection. Even commercially pure aluminum in clean air at ordinary room temperature oxidizes indefinitely.

The use of adherent inorganic protective coatings on aluminum has long been recognized as efficacious in reducing corrosion rate and prolonging paint life. Since aluminum oxide tends to be protective, it is natural that the most intensive early efforts in this direction should have involved processes for improving the properties of the naturally occurring oxide coating. Anodizing, or electrochemical oxidation, although it is one of the most effective of such methods, is rather costly and time consuming.

## ALODINE†

Early in 1945 a new chemical process was devised for producing an amorphous phosphate coating on aluminum. Its simplicity, speed and economy and the unique properties of the coating have resulted in wide commercial acceptance. It is called the Alodine Process.

Some idea of the effectiveness of the Alodine coating on unpainted 3S Grade aluminum may be had from Fig. 1. All panels were removed from the salt spray cabinet after 300 hr. except the Alodized and anodized panels, which were continued to 800 hr.

Organic protective and decorative coatings, such as paint, likewise require a

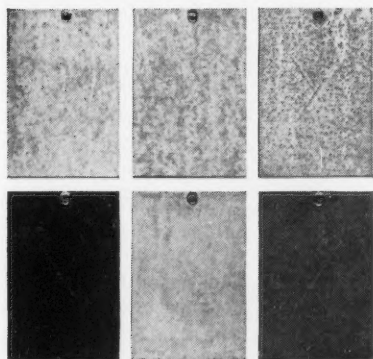


Fig. 1. Salt spray test comparison of Alodine with other surface treatments on unpainted aluminum. (Left to right, top row) solvent wiped—300 hr.; alkali cleaned—300 hr.; phosphate coated—300 hr. (Bottom row) chemically oxidized—300 hr.; anodically oxidized—800 hr.; Alodized—800 hr.

corrosion-retarding undercoating of the kind produced by Alodine to achieve their maximum life and adhesion.

The effect of the Alodine coating in retarding underpaint corrosion is shown in Fig. 2. The Alodized panel was given a top coat only. All other panels in the series were primed after the surface treatments with a regular automotive product, baked, given a surface coat dry-scuffed with sandpaper as per standard automotive practice, and then finished with a regular black baked top coat. The panels were removed from the salt spray after failure of the paint film had set in.

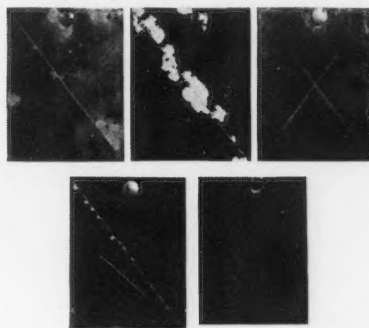


Fig. 2. Salt spray test comparison of Alodine with other surface treatments in retarding underpaint corrosion. (Left to right, top row) alkali cleaned and phosphoric acid dipped—300 hr.; phosphoric acid, solvent cleaned—300 hr.; zinc phosphate coated—400 hr. (Bottom row) anodically oxidized—3000 hr.; Alodized—3000 hr.

## COATING CHARACTERISTICS

The coating produced by this new process is an amorphous metallic phosphate, dense, rather hard, and apparently nonporous. Unlike most oxide films, it is nonabsorptive and cannot be dyed or stained. Sealing in hot water or salts has no apparent effect. It differs markedly in appearance from previously known phosphate coatings, as shown in Fig. 3.

**Electrical Resistance.** Very little information is available at the present time on the electrical properties of the coating, but it is known that resistance increases

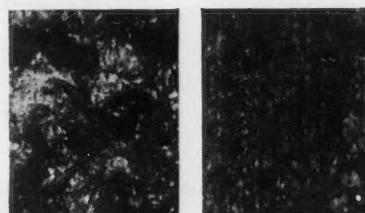


Fig. 3. (Left) conventional phosphate coating on aluminum; (right) Alodine coating produced in 3-min. immersion, rinsed and air dried. Magnification 500 diam.

very rapidly with thickness and as a result coatings normally produced offer extremely high resistance.

**Weight and thickness.** Generally speaking, the weight of the amorphous phosphate coating increases with processing time, bath strength, and bath temperature. It is interesting to note that the increase becomes less and less pronounced as the temperature increases and actually reverses itself into a sharp decline between 130 and 140°F.

**Adhesion.** The original purpose in development of this process was to improve adhesion of the paint to aluminum surfaces and thus lengthen their overall life. Only later was it discovered that the film itself provides corrosion resistance.

**Resistance to Bimetallic Corrosion.** Since it has very high surface resistance, the coating, as would be expected, offers good resistance to bimetallic or galvanic corrosion. Test samples are available to illustrate the insulating effects.

*We present here a general and by no means complete, report on ACP Alodine—its properties and uses in protecting aluminum alloys. Your ACP sales representative can give you a much fuller story. Or write us at Ambler.*

\*Alodine is a registered trademark of Amchem Products, Inc.

†Since the introduction of Alodine amorphous phosphate coatings, ACP has developed a complete line of Alodine amorphous chromate coatings for superior corrosion resistance.

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## More Officials Are Named For Chicago Conference



Jonssen



Kittredge

**JOHN B. KITTREDGE**, the Duriron Co., has accepted the post of co-chairman of the Plastics Symposium for the NACE 15th Annual Conference. Mr. Kittredge is coordinator of plastics development at The Duriron Co. Prior to joining the firm he worked in the fields of industrial protective coatings, plastics glazing materials, electrical casting resins and plastics injection molding. He is a member of the Society of Plastics Engineers and vice-chairman of its national professional activity group on casting. He also is a member of ACS.

**W. S. JANSSEN** co-chairman of the Refining Industry Symposium for the NACE 15th Annual Conference has for the past 22 years been associated with construction, maintenance inspection, preventive maintenance, corrosion control and investigations, mechanical and structural problem investigation and material and equipment testing and evaluation. He has been affiliated with American Oil Co., formerly Pan American Refining Corp., since May, 1936. He has been a member of NACE for 10 years and is a member of Technical Committee T-8 on Refining Industry Corrosion.

**B. G. SCHULTZ** is co-chairman of the High Purity Water symposium. He is supervisory engineer at the Westinghouse Electric Corp., Bettis Plant, Pittsburgh. He is engaged in corrosion and reactor coolant control work. His primary field of interest is radioactivity build-up and its control in pressurized water reactor systems. He formerly was associated with Tennessee Eastman Corp. and served in the army.

## Registration Fees Set For 15th Conference

Registration fee for the Chicago 15th Conference and 1959 Corrosion Show will be \$10 for members of the National Association of Corrosion Engineers. Unless NACE members pre-register for the conference, they will be required to establish their membership at the registration desk by showing their 1959 membership cards.

Registration fee for non-members will be \$15 and for ladies \$10.

### MEMBERSHIP CARDS NEEDED AT CHICAGO

NACE members who are not pre-registered will be required to establish their membership in the association at the 15th Annual Conference in Chicago by showing their membership cards. If they cannot produce their cards they will be required to pay the non-member registration fee.

Registration fee for members is \$10; for non-members, \$15; for ladies \$10.

## Two Conference Committees Merged

Two 1959 Conference committees, previously separate, have been combined for the NACE 15th Annual Conference and 1959 Corrosion Show. The two committees are Local Arrangements and Program Coordinating. D. B. Sheldahl, Sinclair Research Labs., local arrangements chairman and Richard Rue, Program Coordinating chairman will be co-chairmen of the merged committees.

Their committee will work with NACE Central Office in setting up a booth where preprints of technical papers may be ordered. Centrally located bulletin boards showing the floor plan of exhibits and location of various meeting rooms will be provided. The committee will work closely with the hotel to provide equipment needed in symposia and technical meeting rooms. The Chicago Section has been asked to assist by having one of its members present in each symposia or meeting.

## '59 Corrosion Show Exhibitors Doubled

Number of exhibitors who will show their services and products at the 1959 Corrosion Show has almost doubled during the past month. Following is a revised list of companies which have signed contracts.

Aluminum Company of America  
Amercoat Corporation  
Apex Smelting Company  
Bishopric Products Co.  
Wayne E. Broyles Engineering Co.  
A. M. Byers Company  
Carboline Company  
Philip Carey Manufacturing Co.  
Chicago Bridge & Iron Co.  
Coast Paint & Lacquer Co.  
Crane Company  
Crest Instrument Company  
Dearborn Chemical Company  
The Duriron Company  
The Giarlock Packing Co.  
Goulds Pumps, Incorporated  
Heil Process Equipment Co.  
Johns-Manville Sales Corp.  
The International Nickel Co., Inc.  
Kerr Chemicals, Inc.  
Kraloy Plastic Pipe Co.  
Magnaflux Corp.  
F. H. Maloney Co.  
Metallizing Engineering Co., Inc.  
National Carbon Company  
Owen's Corning Fiberglas Corp.  
Charles Pfizer and Company, Inc.  
Rust-Oleum Corp.  
Shell Chemical Corp.  
Shell Oil Company  
Standard Magnesium Corp.  
The Tapecoat Co.  
Valdura Division.  
American Marietta Company  
Visco Products Company  
T. D. Williamson, Inc.

## New Correspondents

New correspondents to function in the ferrous metals and power fields have been added to CORROSION's staff. C. P. Larrabee, U. S. Steel Corp., Monroeville, Pa. will be responsible for ferrous metals and Herbert W. Dieck, Long Island Lighting Co., Hicksville, N. Y. will be responsible for the power industry.

## Entertainment Program at Sherman Is Progressing

Although arrangements have not been fully completed, P. E. Henneberry, Amercoat Corp., chairman of the entertainment committee for the NACE 15th Annual Conference and 1959 Corrosion Show has a number of acts arranged with the Hotel Sherman for entertainment at the banquet and a 15-piece orchestra for dinner music and dancing. The entertainers have performed at Radio City Music Hall and on national TV programs.

Mrs. Ann Janota and Mrs. L. Risetter, co-chairwomen of the Ladies Program Committee announce plans to entertain the ladies at the world famous Martha Logan Kitchens, March 17. Miss Lee Phillips, a Well-known television personality appearing on the Columbia Broadcasting system will entertain the ladies with her Hat Style Show on March 18. Details for Thursday's entertainment has not been worked out.

More than a thousand NACE members and 246 technical advisers are members of NACE technical committees.



**NATIONAL and REGIONAL  
MEETINGS and  
SHORT COURSES**

### 1958

Oct. 5-8—Northeast Region. Somerset Hotel, Boston, Mass.  
Oct. 15-17—North Central Region. Cincinnati, Ohio.  
Oct. 20-24—South Central Region. New Orleans, Roosevelt Hotel.  
Nov. 17-19—Western Region. Los Angeles, Statler Hotel.

### 1959

March 17-19—15th Annual Conference and 1959 Corrosion Show. Sherman Hotel, Chicago.  
Oct. 5-7—Northeast Region. Lord Baltimore Hotel, Baltimore, Md.  
Oct. 12-15—South Central Region Meeting, Denver, Col.  
Oct. 20-22—North Central Region, Cleveland.

### 1960

March—16th Annual Conference and 1960 Corrosion Show. Dallas, Texas, Memorial Auditorium.  
No dates set—South Central Region Conference, Tulsa, Okla.  
Oct. 11-14—Northeast Region Meeting. Huntington, W. Va.

### 1961

March—17th Annual Conference and 1961 Corrosion Show. Buffalo, N. Y., Hotel Statler.  
Oct. 24-27—South Central Region Conference, Houston, Shamrock Hotel.

### 1962

March—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.  
October 16-19—South Central Region Conference, San Antonio, Texas.

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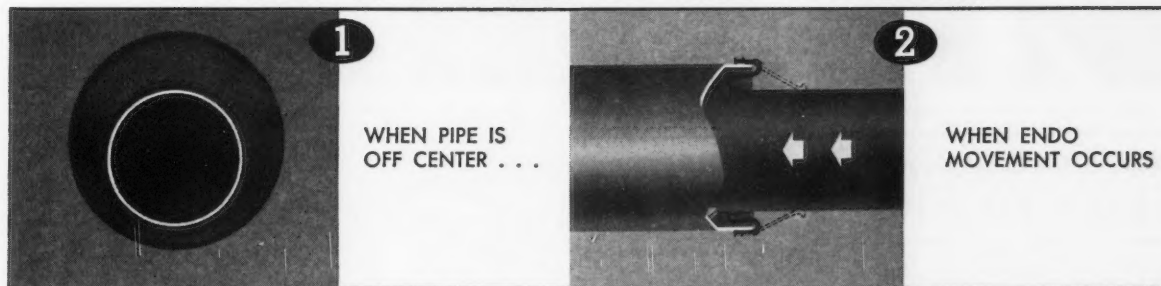
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**1**

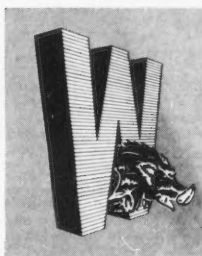
WHEN PIPE IS  
OFF CENTER . . .

**2**

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MOVEMENT OCCURS

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Schwerdtfeger



Southwell



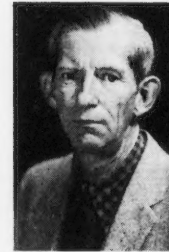
Stern



Sudrabin



Uhlig



Waldron

## NORTHEAST REGION AUTHOR BIOGRAPHIES

**ALLEN L. ALEXANDER**—Is active in several technical societies, especially in the American Chemical Society and in National Association of Corrosion Engineers. He has held offices in the Chemical Society of Washington (Washington Section, ACS), and in the Paint, Plastics and Printing Ink Chemistry Division of ACS. In NACE he was successively elected secretary-treasurer, 1952; vice-chairman, 1953; and chairman, 1954 of the Baltimore Section. He was chairman of the symposium on Organic Coatings for Tankers at the 1952 NACE National Conference, and a lecturer in NACE short courses at the universities of Tennessee and California.

He also has held offices in the American Society for Testing Materials. Other technical societies of which he is a member are the Federation of Paint and Varnish Production Clubs, the American Institute of Chemists, Washington Academy of Sciences, and Research Society of America (NRL Branch). He is presently an executive in the chemistry branch of the

U. S. Naval Research Laboratory and was educated at the University of North Carolina with BS, MS and PhD degrees.

**CHARLES W. AMBLER, JR.**—Is Corrosion Consultant, American Zinc, Lead & Smelting Co. He is chairman of the St. Louis Section, NACE and an active member of numerous NACE committee. He holds a BS in mining and an MS in metallurgy from the University of Missouri, School of Mines. He has worked in the mining and metallurgical industry for 25 years and served five years with the Corps of Engineers in World War II.

**EDMUND A. ANDERSON**—Has been a member of NACE for 13 years, joining in 1945. He is now the NACE corporate member representative of his firm, The New Jersey Zinc Co. of Pennsylvania. He has been in active charge of corrosion work for his firm for 33 years and holds a PhD degree (1920) and an MS degree (1923) from Yale University.

**KENNETH N. BARNARD**—Is a graduate of the University of Saskatchewan with a BSc and an MSc. He has done extensive work investigating corrosion and its prevention for underwater hulls of naval ships at H.M.C.

Dockyard, Halifax, Nova Scotia. He has been a member of NACE since 1949.

**MORTIMER C. BLOOM**—Corrosion consultant, Metallurgy Division, U. S. Naval Research Laboratory, Washington, D. C., was a private consultant before joining the Naval Research Laboratory in 1949. He has a BS in chemical engineering from Massachusetts Institute of Technology (1922). After six years in the paper and petroleum industries, he returned to MIT to earn a PhD in physical chemistry and to work as a research associate in crystal chemistry and electrochemistry.

**A. WINSOR BROWN**, manager of flake products development, at the Reinforced Plastics Laboratory of Owens-Corning Fiberglass Corp., Ashton, Rhode Island. Graduated from the U. S. Naval Academy in 1936 with a BS degree in mechanical engineering. Joined Owens-Corning Fiberglass Corp. in 1940. Worked in various field engineering capacities, specializing mostly in electrical insulation applications. In 1954 made commercial development manager for Fiberglass flake. Transferred to present position in laboratory in July, 1957.

**J. A. H. CARSON**—Has been engaged in corrosion research for the Defence Research Board

(Continued on Page 82)





Carson



Chinn



Christie



Compton



Copson



Cox



Horst



Kemp



Kimberly



Kronstein



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Peterson



Phillips



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Rogers



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## NORTHEAST REGION MEETING ABSTRACTS

### Theory and Principles Symposium

**Polarization Measurements**, by H. H. Uhlig, Corrosion Laboratory, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

A discussion of methods for measuring polarization, what such information provides, and its significance with regard to corrosion rates. It will be shown in what manner the behavior of many corrosion-resistant alloys depends on their ability to polarize anodically and to become passive.

**Electrochemical Methods for Measurement of Corrosion Rate**, by Milton Stern, Metals Research Laboratories, Electro Metallurgical Company, Division of Union Carbide Corp., Niagara Falls, N. Y.

In recent years, a variety of methods have been described which relate electrochemical measurements to corrosion rate. Some are based entirely on empirical observations, while others are supported by both theory and experiment. The methods are described and analyzed in

terms of their dependability, accuracy, and versatility. Suggestions are made concerning the most appropriate areas for practical application.

**Studies on Oxygen Reduction Polarization Reactions**, by Andre J. deBethune, Truman S. Licht, Anthony T. Pawlowski, David C. Curran and Alexander J. Fekete, Chemistry Department, Boston College, Chestnut Hill, Mass.

The reduction of oxygen represents the cathodic portion of anodic-cathodic corrosion couples in most cases where acids ( $H^+$ ,  $Fe^{++}$ ) are not present. The reduction of oxygen in neutral medium should begin at a potential of +0.57 volt to SCE (cathodic to SCE) according to the emf series. Polarization studies by the voltammetric technique have shown that on noble metals, the reduction of oxygen does not begin until the potential of the SCE is reached, i.e., the oxygen reduction overvoltage is about 0.57-volt. Active metals (anodic to SCE) reduce oxygen spontaneously by local action at their resting corrosion potentials. The initial reduction step appears to be  $O_2 + e^- = O_2^-$  with the formation of the unstable anion  $O_2^-$  of perhydroxyl  $HO_2$ . The potential of this reaction is close to that of the SCE. With increasing cathodic polarization, a limiting diffusion current is reached of about  $10^{-4}$  a/cm<sup>2</sup> (100 ma/ft<sup>2</sup>) for air saturated solutions under conditions of natural convection. At this current density, the potential

## Northeast Region's Oct. 6-8 Program Virtually Complete

The most important part of the Northeast Region Meeting—the technical program—is virtually complete. The meeting will be held October 6-8, 1958 in Boston. Most of the 50 authors of the 42 technical papers scheduled for presentation have submitted abstracts.

The technical program will consist of nine separate technical meetings. There will be two sessions for each of the following symposia, Marine Corrosion, Cathodic Protection and Protective Coatings. Single sessions will be held for symposia on Theory and Principles, Utilities, and General Corrosion. The technical program was published in the June issue of CORROSION on page 70.

Six technical committee meetings will be held also.

jumps to more negative values until the hydrogen overvoltage of the metal is reached. This limiting diffusion current is sharply increased by stirring or forced convection. The reduction of hydrogen peroxide in most cases parallels the reduction of oxygen. Data are presented on systems of Cu, Hg, Fe, Pt, Ti and Al in solutions of  $H_2SO_4$  and NaCl. The polarographic diffusion current constants for  $O_2$  and  $H_2O_2$  at a dropping mercury cathode have been redetermined. The study of oxygen reduction on the anodic side of the corrosion potential is being developed by microcoulometric techniques.

(Continued on Page 84)

## NORTHEAST REGION AUTHOR BIOGRAPHIES

(Continued From Page 80)

of Canada at its Pacific Naval Laboratory in HMC Dockyard, Esquimalt, British Columbia since graduation from University of British Columbia with a BSc in chemical engineering in 1950. He has specialized in marine corrosion, in particular marine cathodic protection. He is a member of NACE.

**W. K. CHINN**—Since 1952 has been metallurgist with the Naval Research Establishment, Dockyard Laboratory Section, Defence Research Board of Canada, Halifax, Nova Scotia, where he is engaged in corrosion research relating to HMC ships. Born in Cornwall, England, he was educated at Dolcoath Technical College, has a First Class Foundryman's Certificate from the City and Guilds' Institute of London, England. He came to Canada in 1950 and held supervisory positions in both England and Canada in the ferrous and non-ferrous foundry industries before joining the Defence Research Board.

**K. G. COMPTON**—Has worked with corrosion problems for more than 25 years at the Bell Telephone Laboratories, Murray Hill, N. J. During World War II he was a consultant on the deterioration of materials to the NDRC and the Chief of Ordnance. He has also been active on corrosion committees of several technical societies. He received his training at the State College of Washington in electrical and chemical engineering and in electrochemistry.

**HARRY R. COPSON**—Has been active in a corrosion engineering capacity in various technical societies. He is head of the corrosion section of the research laboratory of the International Nickel Co., Inc. He has been chairman of the corrosion division of the Electrochemical Society and was general chairman of that society's 1953 meeting in New York. He was chairman of the AAAS Gordon Research Conference on Corrosion in 1949. In 1946 he was awarded the Dudley Medal of the ASTM. He has been active on many corrosion committees and has written numerous technical papers on corrosion. He has been scheduled to present a paper in each of two symposia at the Northeast Region Meeting.

**GEORGE C. COX**—Retired Army Colonel, is now a consulting engineer on corrosion prevention processes. He received his BS and MS in Electrical Engineering at the North Carolina State College in 1917 and 1926. He did graduate work in metallurgy at Columbia University and in applied electronics and electrochemistry at the Sorbonne University, Paris. Further graduate work on industrial and manpower mobilization was done at the Army Command and General Staff School and the Army War College, followed by a two-year assignment to the War Department General Staff for World War II operational war planning.

Following this assignment he was placed in charge of a project for corrosion prevention in the European Theater of Operations. While on this latter assignment he developed an electrolytic method of descaling the tetraethyl lead containing rust layers from the cargo compartments of gasoline carrying tank ships. These ships were used to transport clean, lead-free drinking water to American and British troops at the time the German Army was polluting the drinking water sources as it retreated. For this he and his organization received a commendation from General Eisenhower.

**DAVID J. CURRAN**—Is presently pursuing graduate studies in analytical chemistry at the University of Illinois. He holds a BS in chemistry from the University of Massachusetts, 1953 and an MS in chemistry from Boston College, 1958. He was an Inco Research Fellow at Boston College.

**ANDRE J. deBETHUNE**—Professor of physical chemistry on the staff of Boston College since 1947. He is a native of Belgium and came to the United States in 1928. His research includes investigations of hydrogen and oxygen over-voltages, gaseous diffusion, electrode processes and cathodic protection. He holds a BS degree from St. Peter's College, 1939 and a PhD from Columbia University, 1945. Research associate with the Manhattan Project, 1942-45. Post-doctoral fellow of the National Research Council at MIT in electrochemistry, 1945-47 and has been at Boston College since. His research work has been honored by the establishment of an International Nickel Co. research fellowship. He is theoretical electrochemistry editor of the *Journal of the Electrochemical Society*, is a member of NACE, of the American Chemical Society, the Electrochemical Society and the Faraday Society. He also is consultant to the Union Carbide Nuclear Co., Oak Ridge, Tenn.

**BURKE DOUGLAS**—Group leader in the Magnesium Technical Service & Development Laboratory, the Dow Chemical Co., Midland, Mich. He was graduated from the University of Colorado in 1949 with a BS degree. He has been active in galvanic anode development for cathodic protection in Dow plants at Freeport, Texas and Midland, Michigan since 1951.

**W. F. FAIR, JR.**—Is coating consultant in the Tar Products Division of Koppers Company, Inc., Verona, Pa. He received an AB from Harvard College and an MS and PhD in chemistry from Columbia University. His past experience includes research work for the Barrett Division of Allied Chemical Corp., several years as professor of chemistry at Manhattanville College in New York City and as Senior Fellow at Mellon Institute on a Koppers Company Fellowship. For 10 years he supervised coatings development work of the Tar Products Division of Koppers Company at its Westfield, N. J., laboratory. Dr. Fair was president of the Society of Rheology from 1945 to 1949, receiving the Bingham Medal in 1950 and was on the Board of Governors of the American Institute of Physics from 1945 to 1951. In 1956 he was president of NACE. Previously he had been chairman of the New York Metropolitan Section, member of the board of directors and vice-president.

**ALEXANDER J. FEKETE**—Is presently pursuing graduate studies in physical chemistry at the University of Connecticut. He holds a BS in chemistry from Fairfield University, 1956 and an MS in chemistry, 1958. He was an Inco Research Fellow at Boston College.

**B. W. FORGESS**—Is in charge of the tropical exposure and laboratory facilities in the Panama Canal Zone for the Naval Research Laboratory. He has been in the employ of the laboratory since 1953, during which time he has been actively engaged in the study of corrosion, protective coatings and the biological deterioration of materials. From 1940 until 1952, he worked for the Special Engineering Division of the Panama Canal as a materials engineer assigned to various research problems and laboratory work concerned with the proposed construction of the third set of locks and the sea level canal. He attended Pennsylvania State University and is a member of NACE.

**W. R. GRANER**—Native of New York City. Received BChE degree from College of the City of New York and MChE from New York University. Seven and one-half years' experience as mechanical engineering draftsman; fourteen years experience in plastics including six years with Federal Telecommunication Laboratories as Senior Chemical Engineer in plastics and dielectrics research and development and eight years with the Navy as Plastics Technologist and Materials Engineer. Presently head of Structural Plastic and Foams Group in Materials Development Branch, Bureau of Ships.

**J. H. GREENBLATT**—Is the Acting Head of the Physical Chemistry and Corrosion Section of Naval Research Establishment, Dartmouth, N. S. He received his undergraduate degrees from Dalhousie University in 1942 and 1943, his PhD from McGill in 1948. In addition to work in corrosion and electrochemistry covering the last ten years, Dr. Greenblatt previously did research in the fields of internal ballistics and gas phase kinetics.

**R. L. HORST, JR.**—Graduated from Columbia University in 1941 with an MS in chemical engineering. He joined the Sales Department Division of the Aluminum Company of America where he has been concerned with a variety of corrosion studies. Horst has published articles on cathodic protection, aluminum and magnesium anodes and aluminum alloy applications in the chemical and processing industries. He is a member of the National Association of Corrosion Engineers.

**J. L. KIMBERLEY**—Is executive vice-president and secretary of the American Zinc Institute, New York, N. Y. From 1944 to 1955 he was sales manager of Continuous Cast Alloy Division of American Smelting & Refining Co. His other experience includes service on the War Production Board, and in the U. S. Navy and work as a metallurgist with Scovill Manufacturing Co., Waterbury, Conn. He has a BS in mechanical engineering from Yale (1928) and an MS in metallurgy (1930).

**MAX KRONSTEIN**—Is research scientist in the Research Division, College of Engineering, New York University. He was born in Basle, Switzerland, studied at various universities in Holland and Germany and received his PhD in chemistry in 1922 from the University of Leipzig. He then entered industrial work; first in Germany and since 1939 in this country until he joined New York University in 1946. Since that time he has been in charge of research projects in the field of surface chemistry and paint technology which have been sponsored by

various branches of the U. S. Armed Services and by private industry. He has published approximately 20 papers in the field of his work.

**TRUMAN S. LIGHT**—Assistant Professor of Chemistry, Boston College, Chestnut Hill, Mass. Has been teaching analytical chemistry and instrumental methods of analysis at Boston College since 1949. His research work includes electrical and optical methods of analysis, electrode processes and the application of electrochemistry to cystic fibrosis. His degrees are from Harvard College (1943) and the University of Minnesota (1949). He is a member of the U. S. Naval Research Reserve, has been affiliated with the Watertown Arsenal Laboratory, and the Children's Hospital of Boston. He is a member of the American Chemical Society, the Electrochemical Society and the New England Association of Chemistry Teachers.

**WALTER A. LUCE**—Is a graduate of Ohio State University in 1943 with a bachelor of chemical engineering degree. He worked as a process engineer specializing in materials problems for the Curtis-Wright Corporation and following duty with the U. S. Navy obtained his MS degree in metallurgy from Ohio State in 1947. Since that time he has been associated with The Duriron Company, Inc., handling sales and development problems in metallurgy and corrosion. He is presently a supervisor in the Development Department with one of the foremost projects undertaken being the application of high silicon iron anodes for cathodic protection.

**WILLIAM D. MANLY**—Associate Director of the Metallurgy Division of the Oak Ridge National Laboratory, is engaged in research on materials problems in reactor development. He was born in Malta, Ohio, in 1923 and attended public schools in Malta and McConellsville, Ohio. He has studied at Antioch College, the University of Notre Dame, and the University of Tennessee. He received his BS and MS degrees at the University of Notre Dame. During the war years he served in the U. S. Marine Corps and saw duty in the South Pacific and in China as Motor Transport Maintenance Officer. Mr. Manly is a member of the National Association of Corrosion Engineers, the American Institute of Mining and Metallurgical Engineers, the American Nuclear Society and the American Society of Metals. He has served in various capacities in the American Society for Metals, being chairman of the Oak Ridge Chapter in the year 1953-54, and being on the American Society for Metals Publication Committee. Mr. Manly's extracurricular activities are hunting, fishing, and Boy Scout work. He is married and has three sons and a daughter.

**SEIGO MATSUDA**—Is research assistant in the Corrosion Laboratory, Department of Metallurgy, at Massachusetts Institute of Technology where he is studying for the doctor of science degree. He received his bachelor of Engineering degree in the Department of Electrochemistry from Yokohama Institute of Technology (Japan) in 1945 and graduated also from Tohoku University in the Department of Metallurgy in 1950. In 1950, Mr. Matsuda joined the Research Institute for Iron, Steel and Other Metals at Tohoku University where he engaged in corrosion research until 1956 when he came to the United States to continue his graduate studies. He is a student member of both the National Association of Corrosion Engineers and the Electrochemical Society, Inc.

**T. P. MAY**—Is manager of The International Nickel Co., Inc., Kure Beach-Harbor Island Testing Station on the North Carolina coast near Wilmington. He was technical manager of the station for three years prior to June 1957 when he assumed his present post. He joined Inco at New York in 1947 after 10 years as head of the Corrosion Section, Chemistry Division, U. S. Naval Research Laboratory, Washington. He has been active in NACE affairs almost since he became a member in 1947. He has served on the NACE board of directors, has been chairman of the publication committee, is the author of a number of papers, most of them on corrosion and has lectured at several corrosion short courses.

**J. L. MILLER**—Graduated from Yale University in 1943 with a BE degree in chemical engineering. He entered the Army and after basic training and three months' graduate work in chemical engineering at the State University of Iowa was assigned to the Manhattan Project. He has been with the National Carbon Company, Division of Union Carbide Corp. for nine years. For the last five years he has been concerned with engineering and promotion of graphite anodes for cathodic protection. He is a member of the National Association of Corrosion Engineers, Electrochemical Society and associate member of the American Institute of Chemical Engineers.

**E. E. NELSON**—Worked at the Naval Research Laboratory for eleven years. This in-

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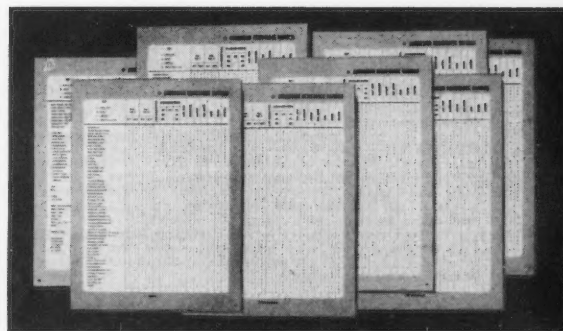
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## NORTHEAST REGION AUTHOR BIOGRAPHIES

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cluded research on lead-acid batteries and cathodic protection. He is now located at the Brooklyn Technical Service Laboratory of Socony Mobil Oil Company as a corrosion engineer. He has been interested in the design of systems for the exterior of hulls and the interior of tanks. Other studies have included current distribution and anode design.

**W. L. PARK**—Native of Washington state. Received BS in Chemical Engineering from the University of Washington in 1926. Employed as analytical chemist at Northwest Experiment Station, U. S. Bureau of Mines on a cooperative agreement with Perin and Marshall, New York for two years and as plant chemist for Crescent Manufacturing Company, Seattle, Washington for one year prior to entering government service at Puget Sound Naval Shipyard in 1929 as assistant chemist. Promoted to supervisory analytical chemist in 1941 and consulting chemical engineer in 1945. In 1954 became supervisory chemical engineer in charge of industrial chemical processes and reinforced plastics research and development section. Promoted in 1956 to chief chemist, Puget Sound Naval Shipyard.

Served as president and chairman of the board of Associated Chemical and Engineering Corporation, manufacturers of specialty chemicals from 1945 to 1950 and as secretary and member of the board of Columbia Gypsum Products Inc., from 1948 to 1950. Presently secretary and general manager of Silverdale Plastic Boat Company.

**ANTHONY T. PAWLOWSKI**—BS, chemistry, Gannon College, 1951; MS, chemistry, Boston College, 1956; Inco Research Fellow at Boston College; presently pursuing graduate studies in physical chemistry at Notre Dame.

**MILLER H. PETERSON**—Is a member of the Consultant Staff (Corrosion) in the Metallurgy Division of the Naval Research Laboratory at Washington, D. C. He received a BS degree in chemistry from Clemson College in 1944, and a MA degree in analytical chemistry from the University of North Carolina in 1951. He has been associated with Clemson College as an instructor in the chemistry department and with the Naval Ordnance Laboratory at White Oak, Maryland where he was engaged in the evaluation of electrochemical ornance devices. Since 1954 he has been at NRL as a part of a group working on the cathodic protection of naval vessels.

**W. L. M. PHILLIPS**—Is a research engineer in the Metal Use Research group, Research and Development Division of The Consolidated Mining and Smelting Company of Canada Limited at Trail, B. C. He graduated in 1950 with a BSc in chemical engineering from the University of Saskatchewan and has been employed with Cominco since that time. He has worked on a variety of research, development and pilot plant projects. Since joining the Metal Use Research group in 1955 he has concentrated on corrosion studies with particular emphasis on atmospheric corrosion and cathodic protection.

**HERMAN S. PREISER**—Is a corrosion engineer for the Bureau of Ships, U. S. Navy Department where for the past seven years he has been engaged as the project engineer in the research and development of marine cathodic protection systems and associated studies. He has written many articles in his field and holds a patent on a new type bilge keel anode. He is a professional engineer in the District of Columbia and in Virginia.

**DAVID K. PRIEST**—Born in Ohio in 1926, he received his undergraduate training at Otterbein College and Ohio State University and degrees of bachelor of metallurgical engineering and master of science from Ohio State University in 1951. He was graduated from the Ohio State University in 1953 with a PhD. He was research associate in the Ohio State University Research Foundation from 1951 to 1953 and at present is manager of the Applied Research Department in the Research Laboratory of the Paudler Co., Rochester, New York.

**T. HOWARD ROGERS**—Joined the Defence Research Board of Canada in 1949 and since 1951 has been Officer-in-Charge, Naval Research-Dockyard Laboratory, a section of the Naval Research Establishment, Halifax, N.S. Naval Research-Dockyard Laboratory is the consultative authority on service failures in metallurgy, corrosion, engineering, etc., to the Royal Canadian Navy, Atlantic Command. Before coming to Canada, he was for over ten years in the Corrosion Department of the British Non-Ferrous Metals Research Association,

London, England; he has published several papers on corrosion and related subjects. Mr. Rogers was born in Warwickshire, England and holds a diploma of the Imperial College, London, England and has a fellowship of the Institution of Metallurgists, London, England and is a member of both the Canadian Aeronautical Institute and the American Society for Metals.

**WILLIAM J. SCHWERTFEGGER**—Is in the Corrosion Section, Division of Metallurgy, National Bureau of Standards, Washington, D. C. Received a BSEE degree from the Newark College of Engineering in 1930. Before coming to the Bureau in 1947, he was employed by the gas division, Public Service Electric and Gas Company of New Jersey. At the Bureau of Standards he has been doing research in cathodic protection and developing techniques for measuring corrosion rates from polarization curves. He has served on cathodic protection committees of the NACE and AIEE.

**CHARLES F. SCHRIEBER**—Joined NACE as a junior member while a student at Texas A & M College from which he holds a BS in chemical engineering. During his senior year he conducted corrosion studies on the effect of agricultural chemicals on aircraft structural materials. In 1955 he presented a paper at an NACE regional meeting. He is a member of NACE, and has been active in technical committee work.

**CHARLES R. SOUTHWELL**—In materials engineering since 1954 engaged in investigating corrosion and protective coating of metals for Naval Research Laboratory, Canal Zone. From 1950 to 1954 he was engineer-in-charge of concrete and protective coatings during construction of International Falcon Dam and before 1950 worked with Special Engineering Division, Panama Canal Company on research pertaining to corrosion, coatings and concrete for design of a sea level canal. He attended St. Mary's University of San Antonio, Texas, majoring in physics.

**MILTON STERN**—Is a Research Metallurgist at the Metals Research Laboratories, Electro Metallurgical Company, Union Carbide Corporation, Niagara Falls, New York. He received a BS in chemical engineering at Northeastern University and an SM and ScD from Massachusetts Institute of Technology in physical metallurgy. He was Weirton Post-doctoral Fellow at the corrosion laboratory of MIT for two years prior to joining the Metals Research Laboratories. Dr. Stern was presented the Young Author's Award of the Electrochemical Society in 1955 and is corrosion division editor of this society. He is also secretary-treasurer of the Niagara Frontier Section of NACE.

**L. P. SUDRABIN**—Consultant to Electro Rust-Proofing Corp., Belleville, N. J. He graduated from Northeastern University, Boston in 1936 with a BS in chemical engineering. Prior to joining Electro Rust-Proofing, Mr. Sudrabin occupied the positions of research engineer with the Dorr Co., chief chemical engineer with the Dayton Powder and Light Co. and chemist with the Boston Edison Co. He is a member of the AIChE, Electrochemical Society, National Association of Corrosion Engineers, National Society of Professional Engineers and is a registered professional engineer in the States of New Jersey, New York, Massachusetts, Connecticut and Ohio. He is active in several technical committees in the National Association of Corrosion Engineers. His experience covers research, development and application of the cathodic protection principle to pipelines, ships, piers and docks; chemical process, power plant, water storage and treatment, oil producing and process facilities, etc. During the last three years, much of his work has been in the Middle East and in the Caribbean.

**BORIS H. TYTELL**—A supervisory chemist with the Boston Naval Shipyard, has had considerable experience in the comparative evaluation of both galvanic anodes and anodes for impressed current systems. He has specialized in a cathodic protection for several years, and is a member of NACE Unit Committee T-3G on Cathodic Protection, T-2B on Anodes for Impressed Currents and Task Group T-3G-1 on Cathodic Protection of Hull Bottoms of Ships. He is a graduate of Brooklyn Polytechnical Institute.

**H. H. UHLIG**—Is head of the MIT Corrosion Laboratory, where he and his associates are studying the whys of corrosion and what to do about it. He began corrosion research at MIT in 1936, continued his studies in this field and in metallurgy from 1940 to 1946 at the research laboratory of the General Electric Company and in 1946 returned to MIT where he is now professor of metallurgy. He is a graduate of Brown University and obtained his doctorate from MIT. Dr. Uhlig has published numerous papers on corrosion, he is editor of the Corrosion Handbook, past president of the Electrochemical Society, a member of the newly established Corrosion Research Council of the Engineering Foundation and a member of the Advisory Committee for the Prevention of De-

terioration Center of the National Research Council. In 1951 he received the Willis K. Whitney Award of the National Association of Corrosion Engineers for contributions to the science of corrosion.

**HUGO W. WAHLQUIST**—Attended the University of Minnesota, receiving the degree of electrical engineer in 1922. He was employed for 15 years by the National Electric Light Association and successor, Edison Electric Institute, New York, engaged in technical investigations with the Joint Subcommittee on Development and Research, EEE-Bell System; American Research Committee on Grounding; Joint Coordination Committee on Radio, EEE, NEMA, RMA; and the National Board of Fire Underwriters—Bare Neutral Wiring Tests. In 1942 he joined the staff of Ebasco Services Inc., New York, and presently is chief corrosion engineer for that firm. In addition to his work in United States, he has conducted corrosion investigations in numerous foreign countries. He has been active in the National Association of Corrosion Engineers, presently serving as chairman of its technical committee on galvanic anodes.

**LEO J. WALDRON**—Is a chemist in the Metallurgy Division of the Naval Research Laboratory at Washington, D. C. He received a BS and MS degree in Chemical Engineering from Michigan State University in 1926 and 1928. Since then he has been associated with the U. S. Navy, National Bureau of Standards and Public Housing Administration doing chemical and metallurgical work. For the last nine years he has been at NRL working on the cathodic protection of Naval vessels.

**J. R. WELLINGTON**—Is a Research Engineer with the Metal Use Research group, Research and Development Division of The Consolidated Mining and Smelting Company of Canada Limited at Trail, B. C. He graduated in 1942 with a BSc in Chemical Engineering from the University of Saskatchewan and, after a period of service in Europe with the Canadian Army, joined Cominco in 1945. Mr. Wellington was for some time in charge of the mitigation of in-plant corrosion problems. Since 1955 he has been associated with the company's metal use research activities, specializing in corrosion studies and new product development. Mr. Wellington is a member of the National Research Council of Canada's Associate Committee on Corrosion Research and Prevention, the National Association of Corrosion Engineers and is active in the work of the American Society for Testing Materials' Committee A-5 (Corrosion of Iron and Steel) and B-3 (Corrosion of Non-Ferrous Metals and Alloys).

**E. R. WELLS**—Group Leader in charge of Coatings Research at Mobay Chemical Company, New Martinsville, West Virginia. He has spent his entire career in coatings formulation, development and research, 24 years with British concerns in England and nine years with prominent American paint companies. He has been with Mobay since September 1956. He was educated at the Imperial College of Science and Technology, London and holds the following degrees: BSc, London 1929; ARCS, Royal College of Science, London 1929; ARIC, Royal Institute of Chemistry, London, 1948.

**L. R. WHITING**—Has been engaged in corrosion preventive work for more than 25 years. He has been with the Bakelite Co. for 22 years. He is a graduate of the University of Kansas and has been a member of NACE since 1947.

## NORTHEAST REGION MEETING ABSTRACTS

(Continued From Page 81)

### Marine Corrosion Symposium

**Lead-2% Silver Alloy as an Inert Impressed Current Anode**, by K. N. Barnard, D. G. Gage and L. G. Christie; read by J. H. Greenblatt.

This paper describes the experimental fitting and trial of lead-2% silver alloy anodes on a destroyer. Specifications for casting and mounting the anodes and auxiliary equipment are given and the operation of the cathodic protection system is described. The performance of lead-2% silver alloy as an inert impressed current anode is analysed and compared with other well known anode materials from both the functional and economic point of view.

**Aluminum Anode Applications on Offshore Structures and Marine Pipelines**, by R. L. Horst, Aluminum Company of America, New Kensington, Pa.

A description of two installations of aluminum anodes in sea water and a discussion of the

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## NORTHEAST REGION MEETING ABSTRACTS

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comparative values of this anode material for cathodic protection applications.

**Uses and Abuses of Aluminum in Wooden-Hulled, Aluminum-Frame Minesweepers**, by T. Howard Rogers and W. K. Chinn, Naval Research-Dockyard Laboratory, Halifax, Nova Scotia.

Generally, aluminum alloys when of the correct composition and correctly used, have been satisfactory in the naval service. Alclad alloys have been very satisfactory in sea water (piping) systems, but non-clad alloys similar to 5357 usually have a relatively short service life when used for tubing carrying sea water.

Service failures have been due mostly to the use of incorrect material; substitution, poor industrial manufacturing, or insufficient technical control. The surveys have shown a definite need for closer liaison between designers and suppliers.

Stainless steel, when used in conjunction with aluminum, is excellent, if the ratio is of the order of 1 to 5 surface area. Zinc chromate properly applied as a corrosion inhibitor for aluminum alloys has been very satisfactory in all locations. Lagging with asbestos definitely should not be used on aluminum alloys in locations where the lagging will absorb moisture. Fibre glass is much to be preferred.

Aluminum corrosion products can be detrimental in lines of small diameter unless well and regularly flushed. Greases and lubricants containing graphite always will tend to cause corrosion of aluminum, often with subsequent seizure.

**A Laboratory Evaluation of Zinc Anodes**, by J. A. H. Carson, Pacific Naval Laboratory, Esquimalt, British Columbia and W. L. M. Phillips and J. R. Wellington, Consolidated Mining and Smelting Co. of Canada, Ltd., Trail, British Columbia.

Previous reported investigations into the characteristics of zinc galvanic anodes in sea water have been confined to studies of the effects of composition under conditions of uncontrolled or a single controlled anode current density. Since the preferred galvanic anode alloy is one that will show little anodic polarization with time over a wide range of current densities, it is desirable to include current density as a factor when comparing alloy performance.

This paper presents data on the anodic polarization of various zinc alloys in natural sea water. The experimental technique and procedures employed are described. Combined effects of iron, as an impurity, over the range 0.0003 to 0.0320%, and aluminum additions over the range 0 to 22%, were investigated at five controlled anode current densities ranging from 0.5 to 20 ma/in.<sup>2</sup> for times up to 100 days. The interrelated effects of iron, aluminum, current density and time are presented by means of graphs and charts. Conclusions are drawn regarding preferred zinc anode alloy compositions.

**Design of Cathodic Protection Systems for Ships' Hulls**, by J. A. H. Carson, Pacific Naval Laboratory, Esquimalt, British Columbia.

A method has been developed for the calculation of the sea-path resistance for various anode-hull configurations. Use of these sea path resistance formulae in determining (a) the current output from galvanic anodes and (b) the optimum width for current shields for high current output anodes, is demonstrated. Supporting data from ship trials are given. Use of the formulae in determining the optimum size, shape and arrangement of anodes is discussed.

### Cathodic Protection Symposium

**Use of the Cathodic Protection Principle in Power Plant Corrosion Control**, by L. P. Sudrablin, Consultant to Electro Rust-Proofing Corp., Belleville, N. J.

The increasing use of the cathodic protection principle to control corrosion on the complex metallic subsurface structures and submerged equipment in power plants is attributable to: a) Recognition of the economic losses from corrosion; b) Better understanding of cathodic protection design requirements and of the criteria for protection; c) The new materials and equipment available for cathodic protection.

Specific attention is given to design considerations in the protection of subsurface networks of dissimilar metals, piers and bulkheads, traveling screens, condenser water boxes, etc.

The adaptation of the newer non-sacrificial anode materials—lead, platinum clad tantalum, etc., to power plant protection are discussed.

**Experiments with Zinc Anodes on Steel Piling**, by John L. Kimberley, American Zinc Institute, New York, N. Y.

A test installation of zinc anodes manufactured in accordance with specification MIL-A-18001 and including a group containing aluminum and cadmium was made on a limited area of the H piles supporting Mystic Pier No. 1 in Boston.

It had been observed that corrosion seemed to be proceeding with undue severity and without consistency from four feet below to two feet above mean low water. The investigation was designed to establish whether spot protection at and adjacent to this area as well as complete protection could be effectively and economically achieved.

The installations were made in a simple pattern and after sixteen months, it would appear that either method of protection (spot or total) could be accomplished and that each system should be given careful consideration.

**Current and Potential Relations for the Cathodic Protection of Steel in a High Resistivity Soil**, by W. J. Schwerdtfeger, Corrosion Section, Div., Metallurgy, National Bureau of Standards, Washington, D. C.

Previous laboratory experiments were carried out in environments having resistivities less than 1000 ohm-cm. It has been suggested that similar studies be conducted in a soil of high resistivity.

In this laboratory investigation 5 steel specimens (tubes) were exposed to a high resistivity soil for 60 days. One specimen was maintained at controlled potential free of IR drop and another at controlled potential including IR. The third specimen was maintained at constant current based on values selected from cathodic polarization curves. The two other specimens were used as controls.

**Electrode Reactions Associated with Galvanic Corrosion of Steel**, by E. E. Nelson, Socony Mobil Oil Co., Inc., Brooklyn, N. Y.

Chiefly a review of the literature to give a more complete explanation of the causes of corrosion. Particular emphasis is placed on reasons why some areas are anodes and some are cathodes.

Published data on the corrosion rate due to hydrogen discharge and to oxygen reduction is tabulated and an attempt is made to correlate this work with theory. An explanation is given as to why the local areas of anodes and cathodes shift to result in general corrosion. Failure to shift causes pitting.

**Application of High Silicon Iron Anodes**, by W. A. Luce, The Duriron Company, Inc., Dayton, Ohio.

The application of high silicon iron anodes for impressed current systems continues to expand and up-to-date information on its range of suitability will be cited. These anodes are used in salt water, in fresh water and in ground beds and recommended service conditions for each of these general fields will be given. New applications are constantly being developed and detailed reference will be made to these uses. Current research on new materials to handle the more severe problems will be outlined.

**Graphite Anodes for Cathodic Protection**, by J. L. Miller, National Carbon Co., Division, Union Carbide Corp., Cleveland, Ohio.

A brief historical review of the early tests and applications of carbon and graphite anodes from the 1934 Ford, Bacon and Davis "Electric Pipe Line Drainage by the Push Pole System" to the most recent tests at Wrightsville Beach, N. C. Reasons for calling carbon an "insoluble" anode material are discussed and the reason for using carbonaceous backfill are covered. The paper closes with a discussion of modern installation practices and illustrations of anodes that have been recovered from abandoned beds.

**Galvanic Anodes as a Supplement to Coatings in Brewery Pasteurizers**, by C. W. Ambler, Jr., American Zinc, Lead & Smelting Co., East St. Louis, Ill.

Zinc galvanic anodes materially lessen the maintenance problems on the water tanks of a brewery pasteurizer. The tanks contain numerous bimetallic couplings in hot aerated water. Paint is ineffective. An organic chromate was only partially effective. Zinc anodes were unaffected by the chromates and effectively controlled the corrosion. Tables and charts show the rate of polarization on a typical 80-hour cycle.

**Cathodic Protection of Steel in Salt Water** by Burke Douglas, The Dow Chemical Company, Midland, Mich.

A discussion of some considerations involved in cathodically protecting steel both continually submerged and alternately submerged in salt water. The role of calcareous coatings in the cathodic protection system will be discussed from both chemical and physical viewpoints.

**Performance of Zinc Anodes for Cathodic Protection in Sea Water**, by L. J. Waldron and M. H. Peterson, Chemists, Consultant staff (Corrosion), Metallurgy Division, Naval Research Lab., Washington, D. C.

The performance of various types of galvanic anodes for use in cathodic protection is being determined in a large scale field test at the Norfolk Reserve Fleet site at Portsmouth, Va. Individual anodes are connected and supplied current to a large steel sea wall. Current was monitored originally by determining the drop across a low resistance shunt with an indicating potentiometer. This has been accomplished recently by the use of ampere-hour meters in the circuit between the anode and sea wall.

The steel cathode is sufficiently large to suffer little or no polarization from the current flowing from the anode. Water at the site is almost equivalent to sea water with an average electrical resistivity of 50 ohm-cm.

Data are given for the current outputs of various zinc anodes containing varying amounts of iron, cadmium and aluminum for exposure periods of 9-12 months. High purity zinc containing a minimum of 0.025% cadmium and 0.1% aluminum gave improved performance. The concentration of these two elements was found not to be critical above a certain minimum. There appears to be an optimum content of aluminum in a low cadmium-low iron-zinc alloy for production of the highest current output.

### Protective Coatings Symposium

**Reactive Coatings**, by Max Kronstein, Research Division, College of Engineering, New York University.

Concerned with coating processes based on chemical reactions between the steel surface and an applied coating material, the material being either a water solution of electrolytes in the presence of organic materials or organic materials with the addition of phosphoric acid. In both cases inter-reactions occur in which the steel surface becomes a part of the resulting coating layer.

A number of these reactions is studied in the course of the paper. In the case of the inorganic surface treatments selection and amount of so-called "metal accelerator" influences the extent of the inter-reaction with the steel. In reactive primers selection of pigment is of great influence on the extent of the reaction and on resulting formation of the surface layer on the steel.

Methods of studying composition of the resulting surface layer are described and the effect of varying components in coating materials is discussed.

**Evaluation of Marine Coatings Exposed to Tropical Environments**, by Allen L. Alexander, B. W. Forgeson and C. R. Southwell U. S. Naval Research Laboratory, Washington, D. C.

Results from exposure of a wide variety of organic coating systems to several conditions of exposure in the tropics. Purpose of the study was to establish relative merits of a number of coatings types for use in protecting structural steel from corrosion under several varieties of local conditions existing in Panama. Data describe the performance of approximately 24 types of coatings based on different resins when applied to steel which has received several pretreatments. Coatings were exposed to immersion in sea water, mean tide and fresh water. Any atmospheric exposures were made at two marine atmospheric locations and at two inland sites removed from the effects of salt laden air. Following the presentation of the exposure data recommendations are made as to the optimum systems to be used for this service.

**Reinforced Plastic Coatings for Metal**, by W. R. Graner and W. L. Park.

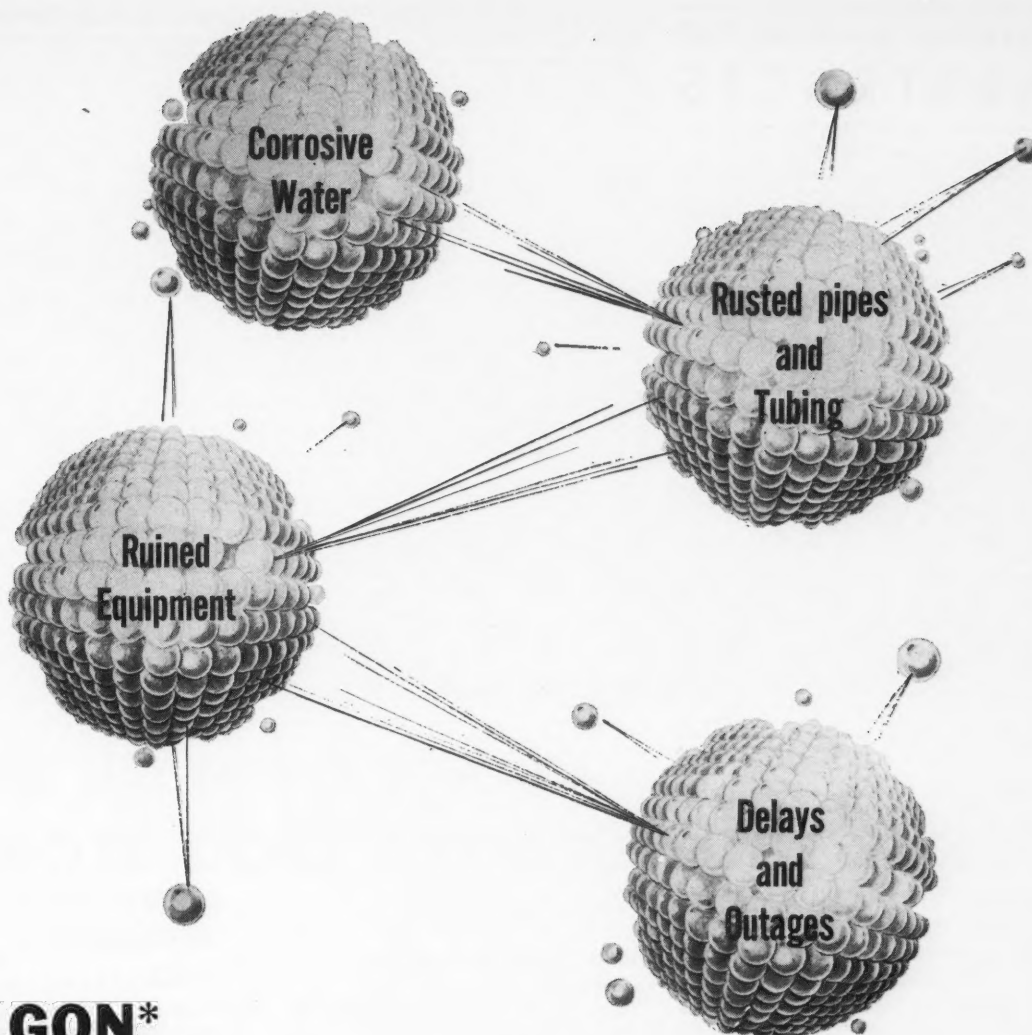
Certain hull areas of steel ships are particularly troublesome from the standpoint of corrosion. In these areas, conventional paint systems are not entirely satisfactory. A program was initiated at Puget Sound to determine whether or not reinforced coatings offer any advantages. Steel panels coated with polyester and epoxy resin formulations reinforced with woven glass cloth were immersed for two years at half tide and full immersion together with control panels coated with conventional paint systems. Results of this exposure are reported. Trial service installations of reinforced coatings on propeller shafts, struts and rudders and other applications are described.

**Pipeline Coating Performance**, by Hugo W. Wahlquist, Ebasco Service, Inc., New York, N. Y.

Results of tests on a variety of pipeline coatings are summarized. The tests cover both

(Continued on Page 88)





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## NORTHEAST REGION MEETING ABSTRACTS

(Continued From Page 86)

laboratory and field investigations of coating performance in soil and water environments. Special characteristics exhibited by Portland cement coatings under cathodic and anodic conditions are discussed, also the pronounced changes observed when certain additives, such as calcium chloride, are used in the cement. Data are presented which show the importance of avoiding excessive cathodic protection potentials on coated structures in sea water and low resistivity soils.

**Corrosion of Glassed Steel**, by Dr. D. K. Priest, The Plauder Co., Rochester, N. Y. The nature of glassed steel is briefly explored and its method of manufacture is reviewed. The mechanisms of corrosion of glassed steel by acid, alkali and water media are discussed and general temperature and concentration limits defined. Variables affecting glassed steel corrosion are discussed. These are principally temperature, concentration and glass structure. Methods of obtaining corrosion data for glassed steel are explained and some data presented. Types of equipment are reviewed and some typical glassed steel industrial installations illustrated.

**Coal Tar Coatings and Surface Preparation**, by Dr. W. F. Fair, Jr., Koppers Co., Inc., Tar Products Div., Verona, Pa.

Coal tar protective coating systems were applied to well cleaned surfaces, both unpainted and primed, in an extremely corrosive environment. Primers, when used, included coal tar primer, several wash primers and various non-bituminous red lead primers selected after screening for physical compatibility with heavy duty coal tar top-coats. All systems applied to sand-blasted surfaces are in excellent condition after five years' exposure. Identical systems applied to well wire brushed surfaces all failed within one year.

Observations made during atmospheric exposure testing of panels coated with several bituminous and non-bituminous systems racked at Kearny, New Jersey, Kure Beach, North Carolina and Ingleside, Texas, will be presented.

**Glass Flake Reinforced Protective Coatings**, by A. Winsor Brown, Reinforced Plastics Lab., Owens-Corning Fiberglas Corp., Ash-ton, R. I.

A different concept in protective coatings is under development involving the use of glass flake as a reinforcement in various types of resin systems for protection of various substrates. The advantages of such systems are believed to be three fold. Primarily the glass flakes, over leafing, antipinholing, and reinforcing in their action, provide a "built-in" vapor barrier. Secondly, the reinforcement of the flake, in non-solvent type systems, permits the application in a single pass of relatively thick, hard coatings with excellent chemical, moisture and temperature resistance. Stress cracking of the coating at the substrate is minimized by the third advantage, a marked reduction in the coefficient of thermal expansion. Resins expand 50 times as much as glass, but in reinforced coatings, the percentage of glass controls the expansion rate.

Resins being tested include epoxy-polyamide, polyester, and epoxy modified polyesters. All show promise in some fields. While emphasis is on heavy duty metallic corrosion protection as the primary application, products under development show considerable promise with concrete, wood, cinderblock and other substrates.

Glass flake is a relatively new product. Studies sponsored by the Army Ordnance Laboratories have shown that laminates made from glass flake and epoxy-polyamide resin systems can have flexural strengths approaching 60,000 psi with excellent impact strength (about 21 ft./lb. per inch of notch) and high moduli. A cross-section of a 0.035-inch polyester laminate reinforced with approximately 50 percent glass flake indicates what the structure of a flake-reinforced protective coating would approximate, shows the tortuosity of the path any corrosive material would have to travel to reach a protected substrate. The glass itself has excellent resistance to acids and moisture and to mild alkalis.

Application methods are under development. Composite materials can be trowelled, and there are indications that efficient spray coatings in single pass thickness from 0.025-inch to 0.125-inch are practical for either horizontal or vertical surfaces.

Test data are presented for resistance to various hot plating solutions, boiling distilled water and conventional salt sprays. Included will be data on several resin systems, at vari-

ous concentrations of glass flake. Photomicrographs show cross-sections of the coatings at varying reinforcement levels.

While glass reinforced plastics have had wide use as electrical insulation, the dielectric strength of such laminates have been dependent almost entirely upon the resin system used, because of interstices in the mat or cloth used to reinforce. Where glass flake is used as reinforcement, dielectric strength is derived largely from the geometry of the laminate, for example, the best glass cloth laminates at a thickness of 0.060-inch show a maximum dielectric strength of about 700 vpm, depending on the resin system used, while glass flake laminates have been made with the same resin systems showing dielectric strengths at these same 0.060-inch thicknesses up to 1600 volts per mil. Insulation resistances are comparably improved.

**Chemically Modified Coal Tar Coatings**, by W. E. Kemp, Koppers Company, Inc., Tar Products Division, Verona, Pa.

The chemistry and physical and chemical characteristics of chemically cured protective coatings resulting from the combination of coal tar with three broad classes of reactive resins are discussed. These reactive resin classes, the diepoxides, the polyepoxides and the polyurethanes when cured with coal tars and amines, esters, ethers and phenolic resins constitute a new class of protective coatings which are of growing importance in the protective coating field. Each system exhibits special properties of its own which are complimentary. The choice of any one system is dependent upon the physical or chemical environment to which the coating will be exposed. Typical applications and service are described.

**Evaluation of Urethane Coatings in Corrosive Exposures**, by E. R. Wells, Coatings Research, Mobay Chemical Co., New Martinsville, W. Va.

Urethanes, one of the newest materials to appear on the coatings scene, have shown extremely good resistance to continuous exposure to high humidity, water-immersion and sour-crude immersion. They also exhibit very good abrasion resistance and exposure to solvents and certain concentrations of acids, alkalis and salt solutions. These coatings have been widely used in Germany for a number of years for plant maintenance and corrosion protection and although they are too new in this country to have accumulated sufficient field history to determine their ultimate role, there seems little doubt that they will challenge the commanding position now held by such established materials as the vinyls, chlorinated rubber and epoxies for applications requiring optimum performance under adverse conditions.

### Utilities Corrosion Symposium

**Liquid Metals for Use in a Nuclear Reactor**, by W. D. Manly, Associate Director, Metallurgy Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Corrosion of structural metals in liquid metals is for the most part due to solubility of the various constituents of the metal or alloy in the liquid metal. The manner in which this solution manifests itself gives rise to many types of attack, ranging from a simple solution type to a deep intergranular with preferential leaching of one constituent of an alloy. Examples of the many types of corrosion experienced with solid metal-liquid metal systems are illustrated. Role of impurities on the corrosion is discussed.

In addition to the solution step, which would soon disappear in a static, one-metal system due to reaching a solubility limit, the corrosion of metals can be continued through the removal of materials from solution in the liquid metal with a temperature gradient or by dissimilar metal transfer. Thus the transfer of metal in a plumbing system by the mechanisms of mass transfer—temperature gradient and dissimilar—will greatly increase the amount of corrosion as compared to the results obtained in static systems. Examples of temperature gradient mass transfer and dissimilar transfer are reviewed and factors governing the occurrence of these phenomena are outlined.

**Instruments for Measurements in Corrosion Work**, by K. G. Compton, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Electrical instruments of various types which have been found useful in underground or underwater corrosion studies or mitigation are described and their limitations discussed. Factors such as accuracy, sensitivity, ruggedness and versatility are considered and recommendations made for instruments for various types of work. Some newer equipment is described which has not become widely used, but which offers promise of improved operation and versatility. A brief description is given of typical uses of various instruments, together with the circuitry involved.

### General Corrosion Symposium

**A Demonstration of Electrochemical Corrosion Reactions by the Use of Transparent Cells in an Optical Projector**, by Col. G. C. C. Consulting Engineer, Charleston, W. Va. Development of these miniature transparent cells resulted from a need to demonstrate the correct and incorrect uses of cathodic protection on coated underground pipe line networks and related structures. These cells have been used to advantage in studying various electrochemical changes or reactions such as: ionic migration rates, electrode reactions, electroplating reactions, etc.

However this presentation will be confined essentially to an illustration of the various corrosion reactions and of methods of preventing or inhibiting such reactions.

**Zinc in the Marine Environment**, by E. A. Anderson, New Jersey Zinc Co. of Pennsylvania, Palmerton, Pa.

To place the behavior of zinc in marine atmospheres and in sea water immersion in proper perspective, data from the literature and from unpublished experiments are reviewed and analyzed. Included are atmospheric studies of cast and rolled zinc and of galvanized iron, sea water immersion tests of zinc and atmospheric and sea water studies of zinc-rich paint.

**Sodium Silicate as Corrosion Inhibitor**, by Seigo Matsuda and H. H. Uhlig Corrosion Laboratory, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

Corrosion rates of Arco iron in aerated sodium silicate and NaOH solutions of various concentrations were measured at 25°C as a function of pH. An anomaly in the corrosion rate was found between pH 9 to 10. The mechanism of inhibition was studied by supplementary corrosion potential measurements and polarization curves in both deaerated and aerated solutions.

**Bibliographic Surveys of Corrosion** published by NACE now cover the years 1945-53 inclusive.

The NACE 15th Annual Conference and Exhibition will be at Sherman Hotel, Chicago.

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A good example is this 8000 foot stretch of new 8" pipe along the new Southside Expressway in downtown Charleston, W. Va. It was installed recently for the United Fuel Gas Company by Saul and McCallister, Inc., of Yawkey, W. Va.

This contractor found that two men, using the Roskoter for application of Roskote 612 XM cold-applied pipe mastic, could keep pace nicely with the welders. The coating specifications called for over-the-ditch cleaning, two 15 mil applications of Roskote 30 minutes apart, followed immediately by wrapping with 15 lb. perforated asbestos pipeline felt.

Roskote 612XM is a cold-applied, fast-drying pipe mastic of high electrical resistivity. Composed of high grade native pyrobitumens homogenized with

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# Foreign Corrosion Control Reports Made for '57

## Australia

A. G. Sussex, Metallurgical Chemistry Group, Commonwealth of Australia, Defence Research Laboratories, Private Bag No. 4, P. O. Ascot Vale W.2, Victoria, Australia.

Activities in corrosion research and development are rather scattered in Australia and in the absence of any appropriate journal, most of the scientific and technical papers tend to be published in overseas journals.

The recently formed Association for Corrosion Prevention now has branches in both Melbourne and Sydney and provision has been made in a new constitution for other state branches to be formed.

Total membership is now 207, comprising 70 sustaining members, 114 ordinary members and 23 students. Each branch held some 8 or 9 technical meetings during the year, but, as yet, no combined meeting or conference has been held.

## Belgium

M. Pourbaix, Centre Belge d'Etude de la Corrosion, 21, Rue des Drapiers, Brussels, Belgium.

Most activities in the corrosion field are coordinated by Cebelcor (Centre Belge d'Etude de la Corrosion). A detailed report on the activities of this group in 1957 was prepared by M. Pourbaix, Director of Cebelcor, and was published in mimeographed form. Only a brief summary can be given here.

Cebelcor has continued its main three functions: a) fundamental and applied research; b) consulting services; and c) organization of corrosion courses, lectures, etc.

Fundamental research has centered on the continuation of the preparation of an atlas of electrochemical equilibria (potential-pH diagrams, etc.); 12 new elements were investigated. Consulting work and applied research dealt with various electrochemical problems: electroplating, cathodic protection, prevention of scale formation in boilers, corrosion in non-ferrous metal industry, etc.

Educational activities were as follows: A course on corrosion (M. Pourbaix), exchange of publications, preparation of films. A meeting for continued collaboration with British investigators was organized in Brussels in April 1957.

## France

Prof. G. Chaudron, University of Paris, Faculté des Sciences, 11 Rue Pierre Curie, Paris 5e, France.

A list of 62 publications dealing with work on corrosion in 1957 was received. The following work is of particular significance according to Prof. Chaudron.

The work of E. Herzog on stress corrosion of steels under pressure of hydrogen sulfide (*Compt. rend.*, **244**, 1499 (1957); *ibid.*, **245**, 2280 (1957); *Rev. Metallurgie*, **54**, 23, 337 (1957)). These investigations are of considerable importance in the French economy because the tubes designed by Herzog (U. S. patent 2,770,563, Nov. 1956) are

## ANNUAL REPORTS FROM TEN COUNTRIES

The following report was prepared by the Inter Society Corrosion Committee's sub-committee on Relations with Foreign organizations\* from the reports submitted by foreign correspondents. The following countries are covered: Australia, Belgium, France, Germany, Italy, Japan, New Zealand, Spain and Switzerland. Correspondents from the following countries did not submit a report: Austria, Denmark, England, Norway, Sweden and The Netherlands.

Addresses of foreign correspondents are given for readers desiring further information.

Composition of the sub-committee: P. Delahay (chairman), G. A. Ellinger, F. Fink, M. G. Fontana, E. Gulbransen, F. L. LaQue, F. N. Speller and H. H. Uhlig.

\* Paul Delahay, Louisiana State University, Baton Rouge, La., chairman.

used in natural gas installations in the Pyrénées district.

The investigations carried out in Prof. Chaudron's laboratory at Vitry: structure of iron-iron oxide interfaces (R. Sifferlen and C. Bourelle, *Compt. rend.*, **244**, 2160, 2928 (1957)), penetration of hydrogen in iron in sodium sulfide medium (J. Talbot and S. Besnard, *Compt. rend.*, **244**, 1193 (1957); *ibid.*, **245**, 965 (1957)), and grain-boundary corrosion of aluminum of high purity (F. Montariol, *Compt. rend.*, **244**, 2163 (1957)).

Investigations directed by Prof. Bénard on dry oxidation of metals and alloys: *Z. Elektrochem.*, **61**, 59 (1957); *Corrosion et Anticorrosion*, **5**, 138 (1957); *Publications Scientifiques et Techniques du Ministère de l'Air*, Paris, No. 327 (1957).

Investigations of J. Herenguel and coworkers (Tréfileries et Laminoirs du Havre) on the oxidation of aluminum (*Rev. Aluminum*, **34**, 1197 (1957)) and zirconium (*ibid.*, **34**, 611 (1957)).

Work of the Saclay center of the French Atomic Energy Commission on the oxidation of magnesium, zirconium and iron-aluminum alloys and other topics: *Rev. Metallurgie*, **54**, 185 (1957); *Méaux, Corrosion, Industries*, No. 1, 10 (1957).

Attention is also called to the papers presented at the Journées d'Automne de la Société Française de Métallurgie in October 1957.

## Germany

Prof. G. Schikorr, Chemische Landesuntersuchungsanstalt, Stuttgart N, Kienstrasse 18, West Germany.

Corrosion has been the object of abundant publications, committee work and meetings.

An important Symposium on Passivity was organized by the Bunsen Society and co-sponsored by The Electrochemical Society and the Faraday Society. This five-day symposium with international participation was held in Heiligenberg-Darmstadt in September 1957. The German Metallurgical Society organized a symposium on stress corrosion. The corrosion committees of several tech-

nical and scientific societies held a joint meeting on corrosion and corrosion prevention in air, water and soils.

Several problems of considerable practical significance were investigated: Stray current in electric traction (German Society of Electrical Engineers); corrosion problems in the packing of electrical equipment during shipping were investigated in connection with meteorological studies during a round-trip Hamburg-Buenos Aires (Council of Maritime Shippers); corrosion protection by galvanization and painting and the effect of surface preparation by sandblasting (Committee for Steel Construction); resistance to corrosion for harbor installations (Society for Harbor Constructions); problems in ship construction and maintenance (Committee of the Society of Ship Builders).

The German Society for Standardization set forth procedures for the following tests: Acid resistance of enameled surfaces, stress corrosion of light metals and thickness of galvanized coatings. Work on corrosion of anodized aluminum through paper is in progress.

## Italy

Prof. R. Piontelli, Laboratori di Elettrochimica, Politecnico di Milano, Piazza Leonardo da Vinci, 32, Milano, Italy.

**Fundamental Research:** In the laboratory of Electrochemistry, Chemical Physics and Metallurgy of the Politecnico di Milano systematic research work has been carried out on the anodic and cathodic behavior of metallic single crystals. The technique involves the following steps: Preparation of single crystals by a modified Bridgman method; orientation determination by X rays; cutting of oriented slices by a chemical-electrochemical method which avoids stresses; electropolishing and surface finishing; control of the orientation by electron diffraction.

The use of plane electrode-surface involves more complicated operations than the more elegant technique, which utilizes spherical single crystals, but leads to quantitative data in the practical absence of interference between areas having different orientation. Also the influence of crystal orientation on hydrogen overvoltage has been investigated.

A group of papers concerning the electrochemical behavior of single crystals of Cu, Ag, Pb, Sn, Cd, Zn, Ni have been published or are in preparation.

Fundamental work on inhibitors has been carried out in the chemical Laboratory of the Ferrara University (Director Prof. L. Cavallaro), and on underground corrosion by Prof. G. Bianchi (University of Modena).

**Applied Research:** The corrosion of iron in concrete has been studied by M. Maraghini at University of Rome, Laboratory of Applied Chemistry, (Prof. Mazzetti, Director).

Quite a number of practical problems has been studied in various industrial laboratories, for instance the corrosion behavior of copper and aluminum alloys in the research laboratory of the company, A. Tonolli, Milan.

(Continued on Page 91)

## Foreign Corrosion—

(Continued From Page 90)

### Japan

T. Fujiwara, Japan Nickel Information Center, 2, 1-Chome, Kyobashi, Chuo-ku, Tokyo.

The Corrosion Committee of the Japan Society for Promotion of Science (K. Ishimura, chairman, Y. Yamamoto, Vice Chairman, H. Shigeno, Secretary).

The committee has been organized to promote scientific and practical understanding on corrosion and to investigate causes and prevention of corrosion. This probably is the largest and most active corrosion group in Japan.

Seventy-one committee members attend monthly meetings at which corrosion problems are discussed. Fifty-four industries provide financial support and 38 other members pay annual fees.

Publications of this group include Corrosion Engineering (6 issues per year) and Handbook of Corrosion Engineering (807 pages, 1957). A two-day corrosion symposium was held in November 1957 at which 17 papers were presented. In addition the following reports were prepared: Corrosion of Al in Hot Water, G. Ito; Mechanism of Corrosion Prevention by Organic Inhibitors, S. Fujii; Characteristics of Anodic Protection of Zinc Base Alloys, H. Shigeno; study of electrolytic coatings, H. Shigeno; and Y. Hisamatsu; Cathodic Protection of Ships, M. Seo; Corrosion Problems in the Oil Refining Industry, Y. Sumino; Electrochemical Corrosion Test of Stainless Steel, G. Okamoto; Discussion on the Testing Methods of Intercrystalline Corrosion of Austenitic Stainless Steel, Stainless Steel Makers; Discussion on the Testing Methods of Hot Sulphuric Acid Corrosion of Austenitic Stainless Steel, Stainless Steel Makers.

Japan Corrosion Engineering Association S. Inouye, chairman.

The association was organized in January 1957 to promote corrosion prevention techniques relating to steel products. The membership comprises makers and consumers of steel products. Projects for discussion are as follows: Standardization of Testing of Atmospheric Corrosion; Rust Preventive Oils (Protective Oil Film); rust preventive packings; surface treatments for short time prevention of corrosion.

Electric Corrosion Control Committee, S. Saheki, chairman.

The committee has been organized to study the protective measures of electric corrosion of electrical equipment, gas pipes and water works. The projects of investigation are as follows: Electric railways, lead cable sheaths, underground pipes, drainage.

Electro-Chemical Corrosion Preventive Committee, G. Okamoto, chairman.

The committee which is affiliated to the Japan Electrochemical Society met three times during 1957 to exchange views on the theoretical aspects of electrochemical corrosion.

Association for Surface Treatment of Metals, Y. Ogawa, chairman.

The association has been established to study practical aspects of plating, surface treatment and painting.

Ship Corrosion Preventive Association. The members of the association met every other month of the year to discuss corrosion prevention for ships.

### New Zealand

F. J. T. Grigg, The Dominion Laboratory, P. O. Box 8018 Govt. Bldgs., Wellington, C. 1, New Zealand.

Activities in the Department of Scientific and Industrial Research!

a) Long-term underground corrosion tests are being continued.

b) The application of Schwerdtfeger potential measurements to the evaluation of external casing corrosion in geothermal steam bores has proved unsuccessful. Consideration is being given to other non-destructive methods for evaluating such corrosion.

c) Corrosion investigations related to the utilization of geothermal steam are in active progress. Tests have been conducted in geothermal bore waters at

240 C and 50 C, containing hydrogen sulphite, chlorides, etc. Stress corrosion and stress rupture tests have been conducted in geothermal steam and water in relation to sulfide stress corrosion by such media. Investigations of hydrogen permeation and saturation phenomena in such media also are in progress.

d) A study of the hydrogen evolution method for assessing intergranular corrosion susceptibility of aluminum-copper alloys, using a 1% hydrogen chloride 3% sodium chloride test solution, has been completed and accepted for publication in the Journal of Applied Chemistry.

e) The potential and polarization characteristics of several commercial copper-brazing alloys are being studied in relation to the galvanic corrosion of

(Continued on Page 92)



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- Only Galvomags, Dow's high-potential magnesium anodes, were used. Several thousand of these anodes were furnished by CSI.
- All chaining, pipe locating and installation was done by CSI.
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## Foreign Corrosion—

(Continued From Page 91)

brazed joints in copper hot water cylinders.

*Activities by other Government Departments*

The corrosive effects of preservative chemicals in treated timbers are being studied by the New Zealand Forest Service.

*Commercial Activities*

No systematic corrosion investigations are known to have been conducted in 1957.

## South Africa

W. J. Copenhagen, S. A. Council for Scientific and Industrial Research, P. O. Box 668, Cape Town.

Two problems were mentioned by W. J. Copenhagen: a) The corrosion of reinforcing steel in concrete in marine atmospheres (see paper by D. A. Lewis and W. J. Copenhagen, *S. A. Industrial Chemist*, 11, No. 10, 13 pages, 1957); and b) the corrosion of tinsplate during stripping.

## Spain

Prof. E. Jimeno, Instituto Espanol de Oceanografia, Alcala, 27, Madrid.

Four publications from Spanish laboratories were published in the *Review of*

*the Iron and Steel Institute* (no reference given by Dr. Jimeno): Influence of anodic polarization on metallic surfaces, measurement of the internal stresses in electrolytic metal deposits, acceleration of cold phosphatization and oxidation of alloys at high temperatures. A paper on the direct phosphatization of marine structures will appear in *The Bulletin of the Oceanographic Institute*.

The hope was expressed by Dr. Jimeno that a central organization for coordination of corrosion research be set up. The existing Spanish organization for metallurgical research, which has proven very successful, could serve as a model.

## Switzerland

Prof. E. Brandenberger, Eidgenössische Material-prüfungs-und Versuchsanstalt für Industrie, Bauwesen und Gewerbe, Zürich.

The following material is taken from the list of publications sent by Prof. Brandenberger: A Study of The Passivity of Nickel (N. W. Herzog, dissertation, Federal Polytechnic Institute, Zürich, 1957); Corrosion Problems in Storage Batteries, K. Vogtli, *Techn. Mitt. PTT*, 35, Nos. 3, 9, 12 (1957); H. Mauch, *ibid.*, 35, No. 6 (1957); Topochemical Study of Corrosion Phenomena, W. Feitknecht, *Corrosion et Anticorrosion*, 1957, pp. 36-50; Performance of Aluminum in Contact with Other Metals in Marine Atmosphere, E. Zurbrugg, *Rev. Aluminum*, 34, No. 244, 647 (1957); Review of Low Temperature Corrosion From Combustion Gases in Oil Burning Plants, F. F. Y. Murray, *Schweizer Archiv.*, 23, 280 (1957); Zinc Powder as Pigment, M. Hochweber, *ibid.*, 23, 169 (1957); Corrosion Caused by Hygroscopic Solids, A. Bukowiecki, *ibid.*, 23, 97 (1957); Corrosion Losses of Fritted Iron, A. Bukowiecki and V. A. Eugster, *ibid.*, 23, 78 (1957).

## Carolinas Section Meets At Wrightsville Beach

The Carolinas Section held its June 6 meeting at International Nickel Co. testing station at Wrightsville Beach following the Seahorse Institute, presented annually by that company.

W. F. Fair, Jr., Tar Products Div., Koppers Company, Inc., formerly president of NACE, and W. H. Kemp, director of coating research with the same firm were present along with two other guests. A discussion was held as to how the section could improve and grow stronger. Guests were invited to participate and they contributed suggestions. J. S. Livingstone, Livingstone Coating Corp., section chairman summarized points of the discussion. The suggestions will be considered in planning for future activities.

In April, the section met at Charlotte, N. C. in a combined meeting with the Carolina Piedmont Section of the American Chemical Society. Joseph Huscher, Kaykor Industries, Inc., spoke on polyvinyl chloride.

## San Antonio Section

Joseph W. Gibson, W. D. Haering Co., San Antonio spoke to members of Alamo Section July 15 on "Common Corrosion Problems in Industrial Equipment." He covered cooling towers, boilers, recirculating systems and air conditioning equipment.



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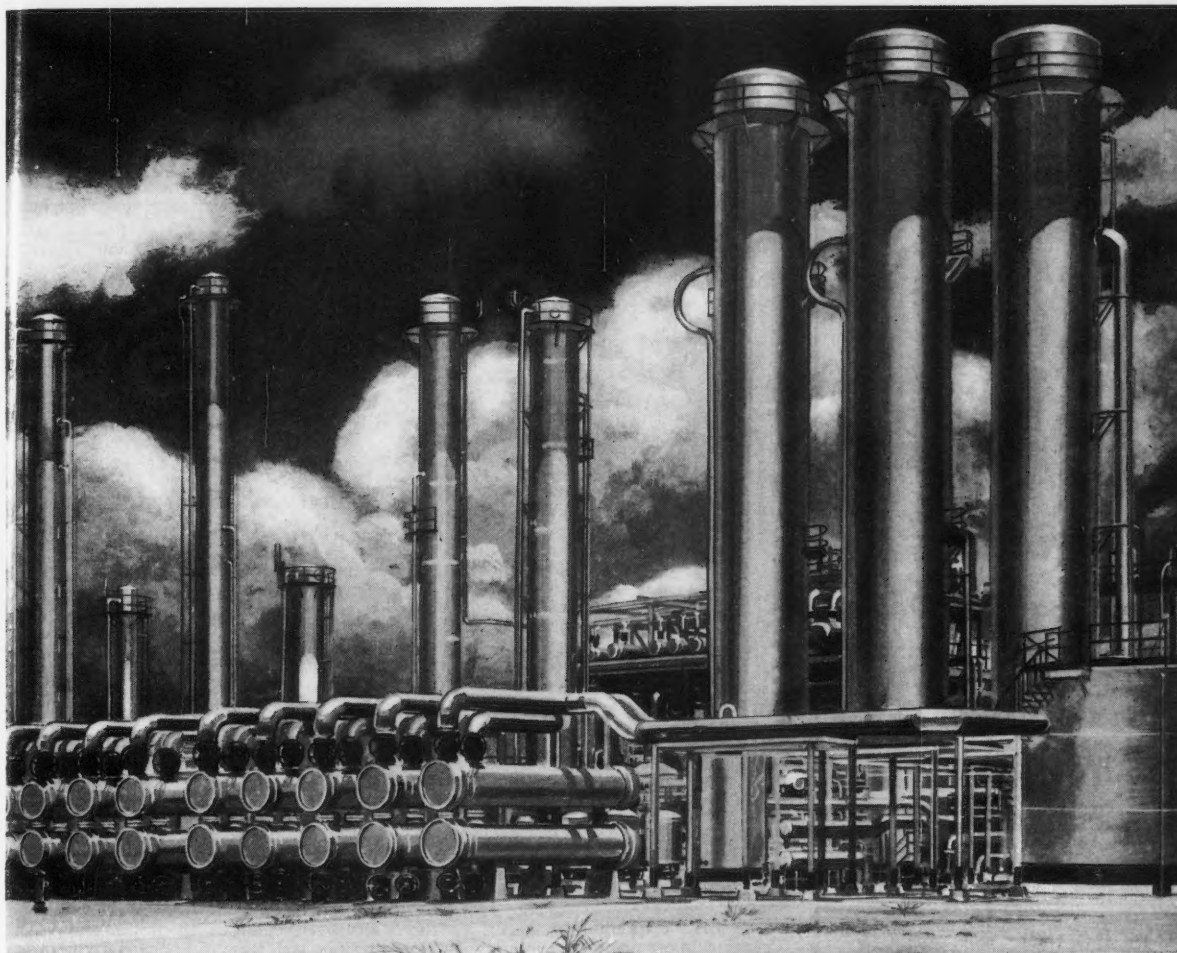
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J. M. PEARSON

## Contributions of J. M. Pearson to Mitigation of Underground Corrosion

Six articles by the late Dr. J. M. Pearson and one by an associate prepared under his leadership are reprinted for the information of new workers and established investigators into underground corrosion problems. Dr. Pearson, recipient of the 1948 NACE Speller Award for achievements in corrosion engineering, is recognized for his outstanding work on problems associated with corrosion of metals underground. The articles, originally published during 1941-44 in *The Petroleum Engineer* and in *Transactions of The Electrochemical Society* are reprinted by permission in this book dedicated to him.

Papers included are:  
Electrical Examination of Coatings on Buried Pipelines  
"Null" Methods Applied to Corrosion Measurement  
Determination of the Current Required for Cathodic Protection  
Concepts and Methods of Cathodic Protection, Parts I, II and III  
Preventive Maintenance by Systematic Pipeline Inspection by Donald F. Van de Water

56 pages, 8½x11 inches, paper cover. 1956. NACE Publication 56-12. Per copy, postpaid.

# \$5

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## Nominations Are Made For South Central Region 1959 Officers

The nominating committee for the South Central Region has nominated the following officers for 1959: J. C. Spalding, Jr., director; J. A. Caldwell, chairman; W. F. Levert, vice chairman; Dan H. Carpenter, secretary-treasurer and Carl M. Thorn, assistant secretary-treasurer.

Mr. Spalding presently is chairman of South Central Region. He is section supervisor of the mechanical, chemical and material and equipment engineering section of Sun Oil Co. He joined the firm in 1947 as drilling fluids engineer and has been active in corrosion work since 1948. He attended Texas A & M, has degrees in basic engineering and chemical engineering from Georgia School of Technology, and has served on the staff of the chemistry department, Southern Methodist University.

Mr. Caldwell is now vice-chairman of the region. He is a past chairman of the Houston Section and a past chairman of Technical Unit Committee T-1D on Sour Oil Well Corrosion and author of several papers on corrosion in oil production operations. He has been active in NACE since 1946. He is now senior research engineer, production research division, Humble Oil & Refining Co. He is a graduate of Louisiana State University.

W. F. Levert is senior corrosion engineer, United Gas Pipe Line Co. He presently is secretary-treasurer of the region and has been a member of NACE since its inception. He is a past chairman of the Shreveport Section. He holds a BS in mechanical-electrical engineering from Louisiana Polytechnic Institute.

Dan H. Carpenter worked for the Tretolite Co. prior to joining Sohio Petroleum Co., 1951 as senior corrosion engineer. He joined Aquaness Department of the Atlas Powder Co., in 1956 as regional sales manager for Kansas and Oklahoma. He has been active in NACE since 1948 and is a past chairman and trustee for the Central Oklahoma Section and was general arrangements chairman for the 1957 South Central Region conference. He is now assistant secretary-treasurer for the region.

Carl M. Thorn is division transmission supervisor for the Southwestern Bell Telephone Co. in San Antonio. He joined the company upon graduating from Texas A & M in 1926 with a BS in electrical engineering. He has been a member of NACE since 1954 and now is trustee of Alamo Section. He is also vice-chairman of the San Antonio Area Corrosion Coordinating Committee.

## New Orleans' Program For Ladies Progresses

Arrangements for the ladies entertainment during the South Central Region Conference in New Orleans, October 20-24 this Fall are almost completed. Breakfast at Brennan's, a buffet, an optional walking or bus tour of the French Quarter have all been arranged. The ladies' luncheon is set for Thursday, October 23.

## Technical Committees To Meet at Cincinnati

Seven technical committee meetings and two educational lectures will be held in addition to the symposia planned for the North Central Region Meeting to be held in Cincinnati October 15-17, 1958.

The technical committee meetings scheduled are: T-2K on Prefabricated Plastic Film for Pipe Line Coating, T-5B on High Temperature Corrosion, T-6F on Protective Interior Linings, Application and Methods, T-3F on Corrosion by High Purity Water, T-5A-4 on Chlorine, T-5A-6 on HI Corrosion and T-7B North Central Region Corrosion Coordinating Committee.

The two educational lectures are, Corrosion in Rocket Technology and Useful Applications of Corrosion.

## Western Region Group Plans Fall Conference

Officials of the Western Region Fall Conference to be held November 17-19, 1958 in Los Angeles met June 25 to discuss the progress made in arranging for the meeting. John Richardson, Amercoat Corp., program chairman, reported the program is nearly complete. Frank V. Wilby, Southern California Gas Co., Los Angeles, was introduced at registration chairman. Another meeting of the committee was scheduled for June 25.

## Baltimore, New Orleans Sections Change Names

Two changes have been made in section names recently. Baltimore Section has been changed to Baltimore-Washington, reflecting the distribution of its membership and New Orleans-Baton Rouge Section has been shortened to New Orleans, recognizing the formation of Baton Rouge Section with which members in that city are affiliated now.

## Meek Accepts Post on '60 Conference Committee

J. Gordon Meek, Metal Goods Corp., Dallas has accepted the post of Assistant General Conference Chairman for the NACE 16th Annual Conference and Corrosion Exhibition to be held March 14-18, 1960. In Dallas, Mr. Meek will work with General Conference Chairman J. C. Spalding Jr., Sun Oil Co., of Dallas.

## LARRABEE HONORED WITH ASTM AWARD

C. P. Larrabee, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa. is one of twelve leaders in the field of engineering materials selected to receive Awards of Merit from American Society for Testing Materials. The awards were made at the ASTM 61st Annual Meeting June 24 at Hotel Statler Boston.





## GENERAL NEWS

### Practical Coatings School Set Sept. 6 and 13

#### Same Program to Be Given On Successive Saturday Sessions

Explanation and demonstration of proper protective coatings application is the theme of the coatings school to be given in September by the Coating Society of the Houston Area. The school will be conducted at the Hanna Construction Company, 9000 Airport Blvd., Houston. Essentially the same program will be given on each of the two days, September 6 and 13. Emphasis will be on practical work.

The program has been outlined as follows:

#### Morning

- 9 am—Opening address, Ross Bacon, Dow Chemical Co., President of the Coating Society of the Houston Area. Additional comments by O. A. Melvin, Carboline Co., school chairman.
- 9:15 am—Why Steel Rusts—Fundamentals by M. A. Riordan, Rio Engineering Co.
- 9:45 am—Coffee break.
- 10 am—Arresting or Preventing Corrosion by Using Protective Coatings or Linings, by Joseph E. Rench, Napko Corp., Houston.
- 10:30 am—Why Test Materials? and What Shows Up in Testing, Carboline Co.
- 11 am—Surface Preparation from Nothing to Sandblasting, Frank Wilson, Clemtex, Inc.
- 11:30 am—Application of Protective Coatings and Linings and Care of Equipment. (September 6, Mr. Stoddard, DeVilbiss Co.; September 13, Wm. Brooks, Binks Mfg. Co.)

#### Afternoon

- 12:30 pm—Lunch.
  - 1 to 5 pm—Visual demonstrations.
- New officers of the coating society are R. H. Bacon, Dow Chemical Co., president; F. Parker Helms, Carbide and Carbon Co., vice-president; M. W. Belue, Champion Paper & Fibre Co., secretary; H. M. Edwards, Petro-Tex Chemical Co., treasurer. O. A. Melvin, Carboline Co., is chairman of the education committee.

#### Australians Offer Prize For Corrosion Control Paper

The Australian Association for Corrosion Prevention, Melbourne Branch, Care of Allied Societies Trust, Kelvin Hall, 55 Collins Place, Melbourne C 1 will pay a prize of 50 guineas (about \$150) to the author of an essay on corrosion control judged most suitable for the association's members. The essay should be on one of the following subjects: Corrosion Prevention in an Industry, Preventing Corrosion by Engineering Design or Preventing Corrosion of Steel Structures Exposed to a Marine Atmosphere.

Entry forms and additional information can be obtained from the association.



**KEY OFFICERS**, both past and present, of the Appalachian Underground Short Course are shown here during the three-day meeting in June held at the West Virginia University, Morgantown, W. Va. Seated left to right are: Charles L. Dey, Koppers Co., new general chairman; and C. M. Rutter, Jr., Equitable Gas Co., new program chairman. Standing are John H. Alm, Dearborn Chemical Co., new publicity chairman; C. A. Erickson, Peoples Natural Gas Co., past general chairman; and J. H. Royston, Royston Labs., past publicity chairman. All are from Pittsburgh.

#### Appalachian Course Attended by 500

Approximately 500 persons attended the Appalachian Underground Corrosion Short Course held June 10-12 at West Virginia University, Morgantown, W. Va. Corrosion engineers and technicians from 29 states and Canada were present.

This year's program included 38 technical papers plus field demonstrations. The program also included exhibits by 32 manufacturers and suppliers of products and services in the prevention of underground corrosion. It was the third annual meeting of the short course.

Officers in charge of the course for next year are: Charles L. Dey, Koppers Co., general chairman; Charles M. Rutter, Jr., Equitable Gas Co., program chairman; T. W. Watson, Socony Mobil Oil Co., publications chairman; George G. Campbell, West Virginia University, exhibits chairman; John H. Alm, Dearborn Chemical Co., publicity chairman; and R. E. Hanna, Jr., West Virginia University, registration chairman. Mr. Hanna is also secretary-treasurer of the school.

#### Laboratory Absorbed

Research laboratories of The Carter Oil Company, Tulsa have been taken over by Jersey Production Research Co. (New Jersey).

#### Stainless Steel Movable Roof on Civic Arena

Stainless steel will be used to fabricate a movable roof 415 feet in diameter over the 14,000-capacity Pittsburgh Civic Arena. Six of the eight sections of the roof will be movable to telescope over two stationary sections. Architects specified 20 and 22 gauge Type 302 18-8 stainless in a No. 2 D special (dull) finish.

The auditorium and its associated facilities will be built on a 94-acre blighted area at the upper end of the city's Golden Triangle.

An average of four to six short courses on corrosion control are held in the United States yearly with cooperation of NACE.



## English Abstracts of Foreign Language Articles Available on Cards

Abstracts of English-language translations of scientific publications from all languages are available on catalog cards on a subscription basis from Special Libraries Association Translation Center, The John Crerar Library, 86 East Randolph St., Chicago 1, Ill. The translation center, partially supported by grants from the National Science Foundation and the National Institute of Health, is a depository for unpublished scientific material which has been translated into English.

Since 1953, when the center was established, the available manuscripts have increased to more than 20,000 items. About 3000 titles a year from Russian sources alone are being received, in addition to translations from other languages.

Mrs. Margaret H. Fuller, librarian of American Iron and Steel Institute, New York is 1958-59 president of the Special Libraries Association.

The American Iron and Steel Institute has given \$25,000 to the translation center.

## IEC Meeting Is Held

The International Electrotechnical Commission, world's standardizing body in the electrical, electronics and communications fields met this year in Stockholm, July 8-17. The United States National Committee of IEC, an arm of the American Standards Association, has announced the registration of 42 delegates for the meeting. Several associated meetings of IEC will be held in the cities of Ludvika and Vasteras, Sweden and in Copenhagen, Denmark, July 1-7.

An average of four to six short courses on corrosion control are held in the United States yearly with cooperation of NACE.

## NEW FRENCH SOLID STATE SEMI-CONDUCTOR READY

Stanislas Teszner, an engineer at France's National Center of Telecommunications Research has developed a new semi-conductor solid state amplifier. Called the Tecnetron, it permits passage of frequencies from 500 to 1000 megacycles and currents of several watts, much higher frequencies than are handled by the transistor.

The device is a rod 2 by 0.5 mm made of negative-electron conductor germanium. In addition to electrodes at each end of the germanium rod a third one, formed by a ring of indium, is placed in a groove in the rod. When brought to a desired potential, this ring interferes with or completely blocks passage of current between the two electrodes.

It has an additional advantage also in that its gain factor grows with the increase in frequency being amplified.

## Plastic Products Design Course Opens September 16

The Industries Training School of Stevens Institute of Technology will offer a new course on Plastic Product Design this fall for persons interested in the structural chemical and electrical properties of thermosetting and thermoplastic plastics. Classes meet Thursday evenings for sixteen weeks beginning September 26.

## Packaging Meet Postponed

The First Annual Industrial Packaging Training Conference has been rescheduled for September 7-20 at the Industrial Management Center, 56C Robbins Road, Lexington, Mass.

## BOOK NEWS

**Constitution of Binary Alloys.** Second Edition. By Max Hansen and Kurt P. Anderko. 1305 pages, 6 x 9 inches. May 16, 1958. The McGraw-Hill Book Company, Inc. 330 West 42nd St. New York 36, N. Y. Per copy, \$32.50.

A translation into English of the classical German work in binary alloys. Reliable data are given on the constitution of binary alloy systems and crystal structure of metallic phases. About 9600 literature references through the spring of 1955 are considered and included. Numerous papers published in 1956 and 1957 are included also.

The second edition considers 1286 systems and 684 diagrams. An important difference between the English language edition and the German edition is that diagrams are presented in atomic percent rather than weight percent. Conversion factors and tables are made available.

Crystallographic data are given respecting symmetry of intermediate phases and lattice spacings. Literature dealing with lattice parameters of primary solid solutions also has been considered.

Appendices include tables of physical properties of the elements, their structural data, crystal structure types, temperature conversions, interconversion of atomic and weight percentages and index of the elements.

**Proceedings, American Society for Testing Materials.** 1409 pages, 6 x 9 inches, cloth. Vol. 57, 1957. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. Availability not indicated.

The annual proceedings of ASTM. Including committee reports and technical papers for the calendar year 1957.

**A Bibliography of Literature Relating to Fouling and Its Prevention.** 236 pages, 7 x 8½ inches, paper. May, 1958. A.C.S.I.L. Library, Royal Navy Scientific Service, Admiralty, Queen Anne's Mansions, St. James Park, London, S.W. 1, England. Availability not indicated.

A mimeographed list of 1942 abstracts taken from published and readily available sources with the exception of two compilations published in the United States.

The list is divided into two sections, Chemical and Technological Literature (90 pages) and Biological Literature. Most of the data relate to steel ships with only a few references to wood borers.

Arrangement is alphabetical by author's name. Anonymous articles are listed under the name of the publication.

**Metallkorrosion—General Information, Measurement, Prevention.** Second Edition. (In German) By Fritz Todt. 122 pages 5¼ x 7½ inches, cloth. 1958. Walter de Gruyter & Co., Genthiner Strasse 13, Fernruf 24-43; Berlin W 35, Germany. Per Copy, DM 16.20.

After discussing the economic importance of the corrosion of metals, the book goes into the causes, reactions of metals and alloys, electrochemical phenomena, inhibition and passivation, cor-

(Continued on Page 97)

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- Tank Car and Vessel Painting and Lining
- Solvents, Proper Use, Selection and Care

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## BOOK NEWS

(Continued From Page 96)

osion by chemicals, types of corrosion and other similar matters.

Detection methods, influence of time on corrosion rate, methods of laboratory measurement, accelerated testing and instrumentation are discussed. The final portion of the book considers prevention of corrosion in various media including, water, gas, chemicals and others. There is an alphabetical subject index.

**Korrosionstabellen Metallischer Werkstoffe.** Fourth Edition. (In German.) By Franz Ritter. 290 pages, 6½ x 9½ inches, cloth. 1958. Springer-Verlag in Wien I, Molkerbastei, Austria. Per copy, \$16.65.

A revision of this standard German work on corrosion of materials. The book opens with a listing of metals by name (usually of European origin) with their analysis.

The corrosion tables are arranged alphabetically by the corrosive concerned and the various materials for which data are given are listed versus the corrosives. The kind of equipment considered is given and data are included on attack in grams per square meter per day and on millimeters per year. Some information is given in narrative form instead of specific attack data.

Reference are given to 224 sources from which information was derived.

**Plant Engineering Practice.** 694 pages, 8½ x 11½ inches, cloth. 1958. F. W. Dodge Corp., 119 W. 40th St., New York 19, N. Y. Per Copy, \$18.50.

Selected articles from the magazine Plant Engineering are presented to cover the whole field of plant engineering from site selection to maintenance and utilities.

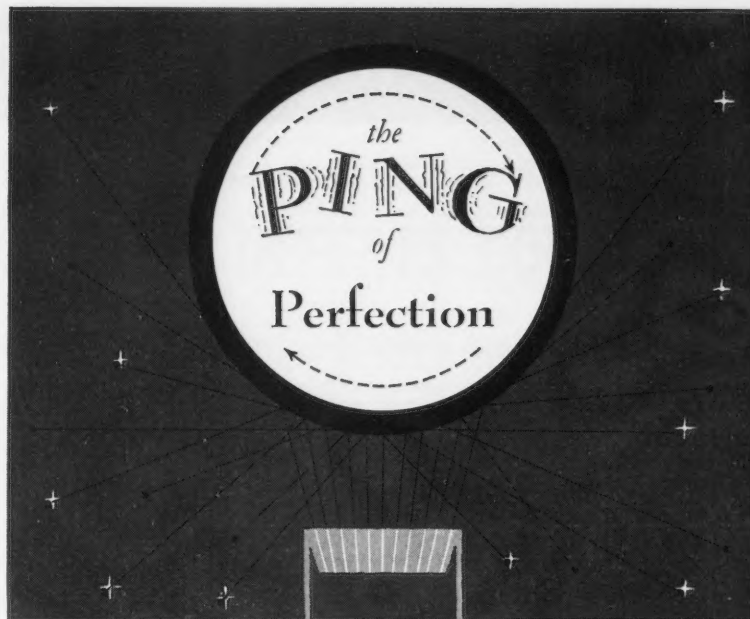
The section on Paints and Protective Coatings opens with a discussion of color, considers a planned painting program, paint roller covers, construction of a paint spray building, automatic spray booths, design for corrosion resistance, heat exchanger tubes, treating steel surfaces, aluminum paint, primers for silicones, curtailing attacks by acids, tank linings, glassed steel equipment, epoxy coatings, plastisols. Most of the information is at the "how to do" level and includes little qualitative information.

## Industrial Smog Control Cost Set at \$9 Million

The Air Pollution Control District of Los Angeles County estimates that measures so far adopted prevent emission into the air of 2000 tons of pollutants daily. This was effected by installation of \$9 million in control equipment and adoption of numerous other measures.

## X-ray Analysis Conference

The Seventh Annual Conference on Industrial Applications of X-ray Analysis sponsored by the Denver Research Institute will be held August 13-15 at the Albany Hotel, Denver.



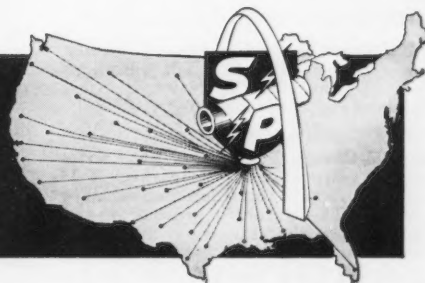
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## Equipment Services

# NEW PRODUCTS

## Materials Literature

### Aluminum

Aluminum can be bonded to stainless steel by pressure, opening possibilities for use of aluminum combined with carbon steel copper and other aluminum alloys, according to Aluminum Company of America.

A 55-foot All-Aluminum tugboat was built by Bryant Boats, Inc., Bayou LaBatre, Alabama in cooperation with Kaiser Aluminum & Chemical Sales, Inc. It is designed for operation in shallow water. The lightness of aluminum contributes to the vessel's 4½ foot draft. The vessel was said to have consumed fewer man hours of construction time than would a similar vessel of conventional materials. No painting except antifouling coatings on the bottom was required.

### Atomic Energy

Alco Products, Inc. has a contract for the entire nuclear system of the first atomic power plant to be built in Alaska. Designated APPR-1A, the second Army Package Power Reactor will be erected for the U. S. Army Corps of Engineers at Fort Greely, near Fairbanks.

Deuterium Oxide, now in surplus at U. S. Atomic Energy plants is available for sale without special license or access permit in quantities of not less than 125 pounds per shipment or more than 500 pounds a year. A special order form to be used for all non-government purchases is available from Savannah River Operations Office, U. S. Atomic Energy Commission, P. O. Box A, Aiken, S. Carolina.

### Backfill

Backfill for galvanic anodes is available mixed to order or in any one of 13 formulas from Charlie Wilson Co., 11531 Main St., Houston 25, Texas. Any combination of Wyoming Arrowhead pure Bentonite, moulding plaster, salt cake, clay, lime, soda ash and gypsum can be blended to specifications in the company's high performance mixers. Backfills take a Class C freight rate.

### Cleaning

Jet Engines are being cleaned without tearing down with ultrasonic vibrations in a vat built for the Navy by Alcar Instruments, Inc., Little Ferry, N. J.

K & E Chemical Sales Co., 129 Pierrepont St., Brooklyn, N. Y. markets K-35 chemical cleaner for stone and masonry surfaces. The cleaner is brushed on and rinsed off with clear water to expose cleaned surfaces.

SRD, a water-soluble chemical, is said by manufacturers Scientific Abrasives, P. O. Box 234, Park Ridge, Ill. to dissolve rust and leave a clean surface and water soluble primer.

### Coatings—Composite

Alcormet, a corrosion-resistant coating material which combines the best properties of the ceramic and metallic elements from which it is made has been licensed for use by manufacturers of water heaters, furnaces and other heating equipment. The coating is made by Solar Aircraft Co., 2200 Pacific Highway, San Diego 12, Cal.

Tungsten Carbide, aluminum oxide and other materials can be applied to metal surfaces by means of a method developed by Linde Company, Division of Union Carbide Corp., 300 Madison Ave., New York 17, N. Y. The flame-plating process involves a special gun into which oxygen and acetylene are fed along with particles of powdered materials to be deposited. When the flame is ignited a detonation drives the particles through the gun barrel into the surface of the work. As-coated smoothness is 125 microinches rms which can be finished down to better than one microinch rms. Coatings have a porosity of less than one percent.

### Coatings—Organic

Peel-It Weathergard, a strippable plastic coating protects metal surfaces against their environment for periods up to three years depending on thickness. It is manufactured by Harco Chemical Co., Cranford, N. J.

Hypalon, polyurethane and Saran coatings, as well as rubber and vinyl combinations are covered in the latest edition of Wilbur & Williams Company's Check Chart for Maintenance Painting. Copies are available from the company at 130 Lincoln St., Brighton 35, Mass. The chart lists in tabular form as vertical ordinate, a variety of surfaces to be painted; the horizontal ordinate covers type of surface, special requirements, recommended product, surface condition, resistance to chemicals, weathering and numerous other considerations.

Hypalon modified with phenolics and epoxies are used in the Plasite series of coatings made by Wisconsin Protective Coatings Co., Green Bay, Wis. They are recommended for use as linings for tanks holding 73 percent caustic and oxidizing agents.

Polyethylene linings can be applied successfully to large tanks using a method developed by Tank Lining Corp., 246 Washington Road, Pittsburgh 16, Pa. The method involves special preparation of the surface and spraying on of a specially prepared high molecular weight, high density, low press polyethylene, followed by a carefully controlled heat treating process. Licensing of the method is offered to responsible applicants.

Gulf Metalcoat-A, developed by Gulf Oil Corp., P. O. Box 1166, Pittsburgh 30, Pa. is an aluminum pigmented liquid

coating including rust inhibitors designed to provide long-term protection for metals exposed to marine and industrial atmospheres. Application to surfaces not entirely rust free is possible.

Robeson-Preserve Co., Port Huron, Mich. has tested a silicone containing high gloss finish for three years on a private airplane and two years on an automobile. Both tests reveal the original color and brightness of the finish virtually unimpaired although neither was polished after application.

### Coatings—Metallic

Case Institute of Technology, Cleveland has been commissioned by American Zinc Institute to investigate service conditions to which zinc galvanized domestic hot water tanks are exposed in some sections of the United States. Robert C. Weast, acting head of the institute's department of chemistry and engineering, will direct the study.

### Filters

Micro Metallic Div., Pall Corp., 30 Sea Cliff Ave., Glen Cove, N. Y. is making filters for new exotic fuels and their components, including hydrogen peroxide, hydrazine, ethylene oxide and liquid oxygen.

### Insulation

Foamsil, a 99 percent silica cellular material is made in thicknesses to 3 inches and up to 17 x 22 inches for internal and external insulation. Curved segments are available. It has no absorption rate, no capillarity, negligible expansion, and is resistant to all acids except hydrofluoric and hot phosphoric. It is a product of Pittsburgh Corning Corp., 1 Gateway Center, Pittsburgh 22, Pa.

### Insulators

Insulated Pipe Unions for use on residential water heaters to stop galvanic currents flowing between the heater and piping system are made by Universal Controls Corp., P. O. Box 13122, Dallas 20, Texas. The unions are made in all pipe sizes, ½ inch to 2 inches inclusive. The company also makes meter insulating nuts and unions, with nylon inserts.

### Instruments

Lenox Instrument Co., 2012 Chancellor St., Philadelphia 3, Pa. makes borescopes ranging in size from a few inches to more than 60 feet in length. Viewing of inside surfaces at various angles is possible through use of attachments, lighting is integral and ultraviolet light can be projected for inspection methods involving particles sensitive to this form of radiation.

Optical Goniometers permit chemists to identify crystalline substances by externally measuring interfacial angles of

(Continued on Page 100)





News from

# National Carbon Company

Division of Union Carbide Corporation • 30 East 42nd Street, New York 17, N. Y.

Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco. IN CANADA: Union Carbide Canada Limited, Toronto

## "KARBATE" EQUIPMENT DEFEATS CORROSION

**National Carbon Representatives expand your Engineering Force**



**E. R. HOGAN,**  
SALES ENGINEER

After graduating from Lehigh University with a B.S. in Mechanical Engineering, Mr. Hogan spent two years in the engineering department at National Carbon's Fostoria plant. Here he worked on the design and installation of equipment for the manufacture of carbon and graphite.

For the past 5½ years Hogan has been a sales engineer in the western New York and Pennsylvania area, working with chemical, steel and electrochemical industries on the application and use of carbon, graphite and "Karbate" impervious graphite materials.

### "Karbate" Heat Exchangers to be shown at Heat Transfer Conference

National Carbon's complete line of "Karbate" impervious graphite heat exchange equipment will be on exhibit in Booth 28 at the Second National Heat Transfer Conference and Exhibit. This event, jointly sponsored by A.I.Ch.E. and ASME, will be held at the Edgewater Beach Hotel in Chicago, Illinois, August 17th thru 20th, 1958.

**"Karbate" impervious graphite provides dependable, economical performance in tough corrosive services.**

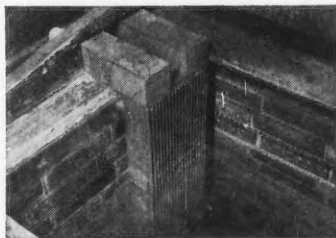
### Pumping Nitric-Hydrofluoric Acids



The almost universal corrosion resistance of "Karbate" impervious graphite permits efficient handling of both individual and mixed acids. This is proved by the performance of a "Karbate" type F centrifugal pump in a nitric hydrofluoric pickling solution (16-18%  $\text{HNO}_3$ , 4% HF) at a temperature of 140° F.

While metallic pumps failed in this service in a matter of weeks, the wet end of the "Karbate" unit is in excellent condition after *six months service*.

### Heating Nitric-Sulfuric Acids

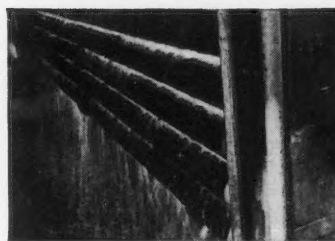


High heat transfer rates, freedom from corrosion and exceptionally rugged construction make these "Karbate" impervious graphite plate heaters an excellent choice for tough heating services. One such unit (replacing a metal heater

that lasted only a few weeks) has given *two years trouble-free service* in a nitric sulfuric acid pickling solution at temperatures of 170° to 180° F.

Based on this performance, 18 additional units have been ordered for the same application.

### Cooling Sulfuric Acid



*Eight to nine years' service* with "Karbate" cascade type coolers in sulfuric acid service has been reported by three separate users. The resistance of "Karbate" impervious graphite to corrosion and to thermal shock makes this and similar performance records typical. The equipment is easy to clean and maintain and is sectionalized to permit installations of additional cooling surface. Since "Karbate" impervious graphite resists all concentrations of sulfuric acid up to 96%, these units are ideally suited for cooling of diluted strong sulfuric acids.



"National", "N" and Shield Device, "Karbate" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.



## NEW PRODUCTS

(Continued From Page 98)

crystals. The recently published Barker Index of Crystals makes this method of optical identification quick and simple. Arthur S. LaPine Co., 6001 S. Knox Ave., Chicago 29, Ill. manufactures the instrument.

### Laboratories

Robertshaw Fulton Controls Co. opened its new \$500,000 research center at Anaheim, Cal. in June.

Carpenter Steel Company's new corrosion research laboratory at Reading, Pa., opened June 5 is equipped with heat transfer apparatus, electrical resistance corrosion metering equipment, multi-sample tester, electrochemical high pressure, high temperature corrosion testing and stress corrosion cracking equipment. The corrosion research laboratory has been added to the company's existing research facilities which include a metallographic laboratory, chemical laboratory and others.



### TECHNICAL REPORTS

on

#### HIGH PURITY WATER CORROSION

Symposium on Corrosion by High Purity Water by Committee T-3F on High Purity Water which includes:

Introduction to Symposium on Corrosion by High-Purity Water by John F. Eckel.

Corrosion of Structural Materials in High-Purity Water by A. H. Roebuck, C. R. Breder and S. Greenberg.

Corrosion Engineering Problems in High-Purity Water by D. J. DePaul.

The Importance of High-Purity Water Data to Industrial Applications by W. Z. Friend. Per Copy.....\$1.50

Symposium on Corrosion by High Purity Water. Five Contributions to the Work of NACE Technical Committee T-3F on High Purity Water. Pub. 57-22.

Measurement of Corrosion Products in High Temperature, High Pressure Water Systems by A. S. Sugalski and S. I. Williams.

Corrosion of Aluminum-Nickel Type Alloys in High Temperature Aqueous Service by F. H. Krenz.

Corrosion of Aluminum in High Purity Water by R. J. Lobsinger and J. M. Atwood.

The Storage of High Purity Water by Richard R. Dlesk.

Water Conditions for High Pressure Boilers by D. E. Voyles and E. C. Fiss. Per Copy.....\$1.50

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65¢ per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

### NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg. Houston 2, Texas

### Metals—Ferrous

Amballoy steels made by A. M. Byers Co. will be sold on the West Coast by Shultz Steel Co., South Gate, Cal.

Stainless Steel wire made by Stainless Steel Division, Jones & Laughlin Steel Corp., Box 4606, Detroit 34, Mich. is described in a 20-page manual available on request. The mill also makes rounds, flats, hexagons, squares and special extruded shapes.

Stainless Steel combination windows and storm doors are being made by Sylvan Stainless Products, Inc., 7558 South Chicago Ave., Chicago 19, Ill. from alloys produced by Electro Metallurgical Co., Division of Union Carbide Corp. They are especially useful in marine and industrial environments.

### Metals—Non-Ferrous

Gold, rhodium, platinum, palladium, silver and composites of these metals are now being plated and electroformed by Bart Manufacturing Corp., Belleville, N. J.

Magnesium-Thorium alloys made by The Bettinger Corp., Waltham, Mass. can be coated with ceramics for use in missiles and rockets where high strength and light weight are significant. The alloy is lighter and stronger than either aluminum or magnesium.

Thorium, a component of new magnesium-thorium alloys used extensively in ballistic missiles, is radioactive. Tests by United States Chemical Milling Corp., Manhattan Beach, Cal. indicate that under normal manufacturing operations exposure is well below the safe level. Size of stacks of the material should be limited to 1000 cubic feet and aisle widths should be not less than half the height of stacks.

### Non-Metallics

Crumb-Rubber production at the Goodrich-Gulf Chemicals, Inc., plant at Institute, W. Va. will be expanded by a million dollar addition to production facilities.

### Pipeline Equipment

Rubber Compound Casing Seals made by F. H. Maloney Co., P. O. Box 1777, Houston 1, Texas have ribbed interior surfaces and stainless steel banding.

### Pipe Wrapping

Mummy-Wrap coating and wrapping can be applied now by a combination machine that cleans, coats and wraps continuously over the ditch. The system is made by The Trenton Co., 401 Wolverine Bldg., Ann Arbor, Mich.

### Plants

Cuban American Nickel Co., a subsidiary of Freeport Sulphur Co., will build a hydrogen sulfide generating unit as part of its metallic nickel and cobalt producing facilities at Port Nickle, La. The hydrogen sulfide will be used to re-

fine nickel and cobalt sulfides shipped from Moa Bay, Oriente, Cuba.

Gaido-Lingle Company has put into operation a pipe coating and wrapping plant at 739 Aleen St., Houston 29, Texas.

### Plastics

Handgards plastic gloves are made of 1¾ mil polyethylene material by Plastic-smith, Inc., Box 415, Concord, Cal.

Permatop, a mineral aggregate with plastic binder is said by manufacturers Permagile Corp. of America, 34-43 Fifty-Sixth St., Woodside 77, N. Y. to adhere tenaciously to any clean, cured masonry surface old or new.

Haveg Industries, Inc., 900 Greenbank Road, Wilmington 8, Del. has a new design service for users of heat exchangers, falling film absorbers, towers and chlorine coolers. The service is described in Bulletin D-1.

Vulkollan, a plastic material combining desirable properties of rubber, nylon and steel was said by Kenneth A. Piggott, Mobay Chemical Co., New Martinsville, W. Va. to combine hardness, rigidity, resilience, elasticity, load-carrying, abrasion, oil, oxygen and ozone resistance found in no other material.

Telecon plastic conduit for electrical and communication systems is made by Southwestern Plastic Pipe Co., P. O. Box 117, Mineral Wells, Texas for use in corrosive environments and in water or underground. It comes in diameters from 2 through 6 inches and lengths of 10, 20 and 30 feet. Solvent jointing and extremely light weight are added advantages.

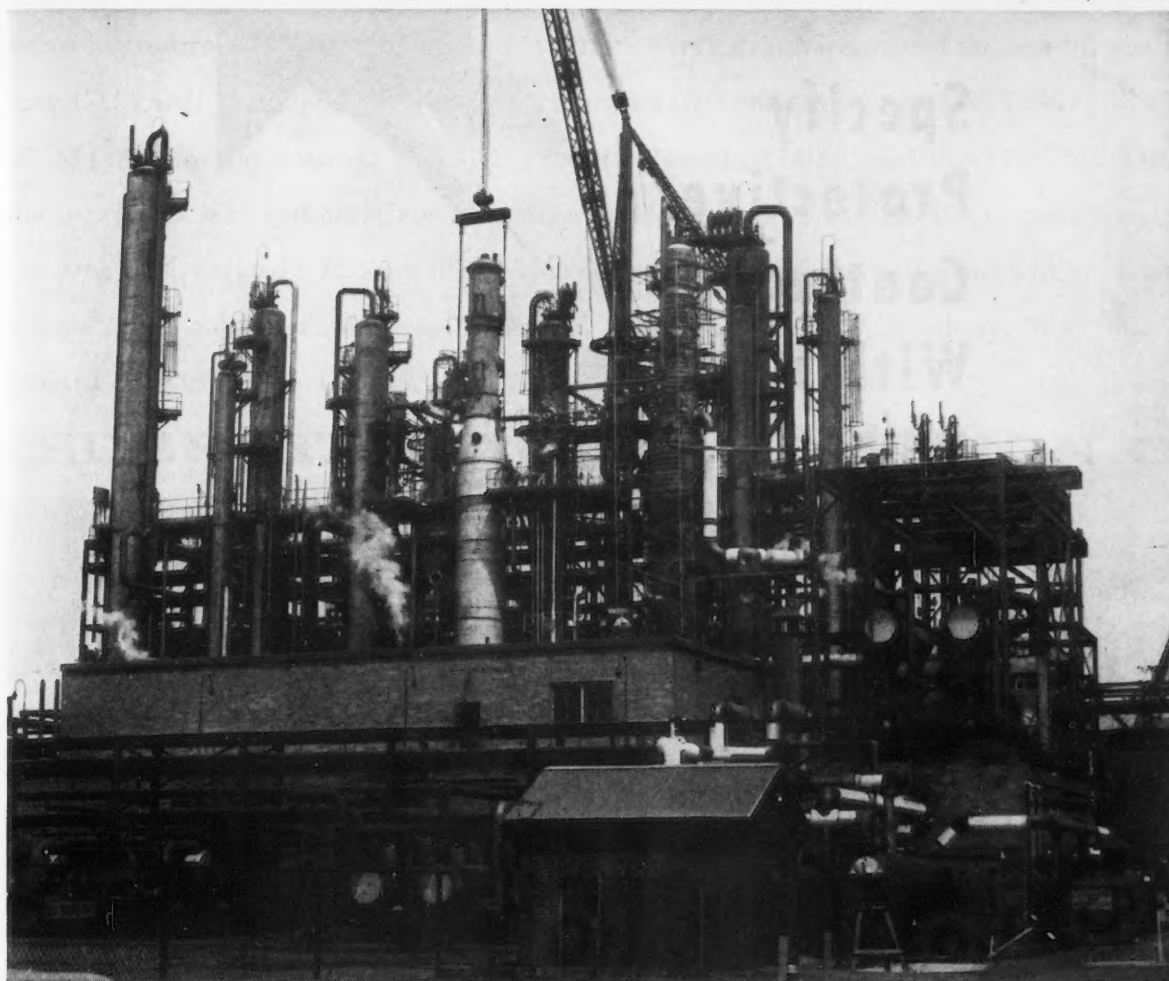
Vinyl Extruded Sheeting 52 inches wide and up to 130 mils thick is being made by National Rubber Machinery Co. and B. F. Goodrich Chemical Co., 3135 Euclid Ave., Cleveland 15, Ohio.

Narmco Resins & Coatings Co., 600 Victoria St., Costa Mesa, Cal. used its Putty 3119 to fill pits and channels in pump diffuser vanes and housings at the Silvergate Power Plant of San Diego Gas & Electric Co. The pumps were being destroyed by the effects of sea water and abrasive particles. A liquid resin formula was applied also to built up areas to protect them against further attack. The applications were reinforced with fiberglass and have been in service for about a year with little or no signs of damage.

Lowell Institute of Technology, Lowell, Mass. granted degrees in plastics engineering to eight students June 15, believed to be the first degrees in this engineering specialty ever conferred.

Mod-Epoxy, an organophosphorus modifier patented by Monsanto Chemical Co., St. Louis 24, Mo. imparts low initial viscosity, accelerates cure and maintains or improves electrical properties of epoxy resin systems. Better resistance to chemicals and water than obtained from unmodified resins or systems is claimed also.

(Continued on Page 104)



Erecting the all-welded, two-part chromium-nickel stainless steel recovery tower at Gary chemical works of United States Steel Corpora-

tion. Graver Tank & Mfg. Co., Inc. of East Chicago, Indiana, fabricated the 90-foot tower and tested it to pressures of 162 psi and 246 psi.

## Stainless steel tower goes up...corrosion comes down... in recovery of aromatic chemicals from coke oven gases

**This chromium-nickel stainless steel tower** recently took over an important job at the Gary Steel Works Coke & Coal Chemicals Div. of U. S. Steel. The big vessel receives hot absorption oils from other parts of the processing plant . . . puts them through its six-tray light oil section, and 15-tray light oil stripper . . . recovers benzene, toluene, and xylene.

**It's a productive but highly corrosive process.** So corrosive that it


knocked out a carbon steel tower in relatively short time. That's why for its replacement the Gary Works decided on Type 304 ELC chromium-nickel stainless steel. This nickel-containing stainless steel can take the corrosive effects of these gases and chemicals . . . it assures *long* service life.

**For your corrosion problems,** it will pay you to consider nickel-containing stainless steels. They are highly re-

sistant to a wide range of organic and inorganic chemicals.

\* \* \*

**A 34-page booklet, "Corrosion Resisting Properties of the Austenitic Stainless Steels,"** is available to you upon request. If you'd like a copy, simply write:

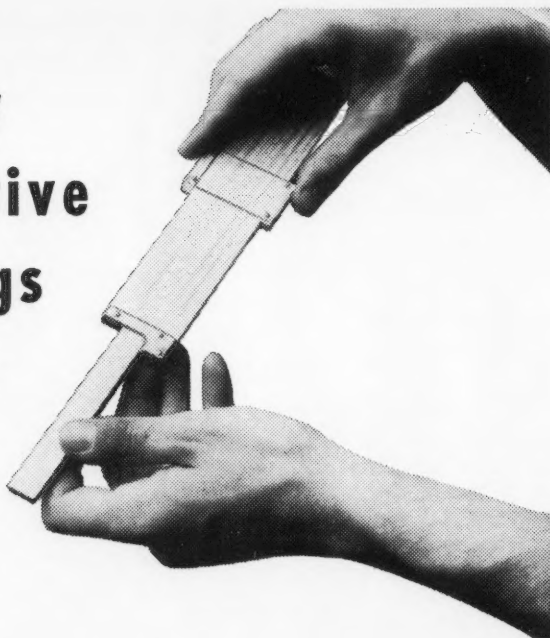
**THE INTERNATIONAL NICKEL COMPANY, INC.**  
67 Wall Street  New York 5, N. Y.

# INCO NICKEL

NICKEL ALLOYS PERFORM BETTER LONGER



# Specify Protective Coatings With a Slide Rule!



## Use Carboline's Engineering Approach!

When an engineer wants an accurate calculation, he doesn't guess — he uses his slide rule.

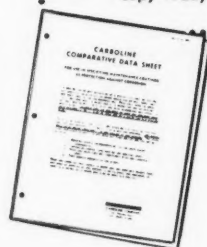
When you buy or specify protective coatings, don't *guess* about the system that is best for your needs. Follow the engineer's example, and use a "slide rule" — a careful, point-by-point comparison of the facts on these important features:

- SOLIDS CONTENTS
- COVERAGE PER GALLON
- MIL FEET PER GALLON
- MIL THICKNESS PER COAT
- RESISTANCE TO CORROSIVE
- ESTIMATED RECOATING CYCLES
- **COST PER SQUARE FOOT PER YEAR OF SERVICE**

Carboline data sheets and recommendations give you all the facts necessary to arrive at a sound, clear-cut conclusion. You will find, on all of these basic points, Carboline Coatings score high. Many Carboline users have discovered the true effectiveness and long range economy of Carboline Coatings by this scientific comparison approach.

Sales Offices in Boston, New York, Pittsburgh, Detroit, Chicago, Houston, Denver, Los Angeles, San Francisco, Toronto and other leading cities.

**FREE** — a 12" x 18" comparative data chart . . . your "slide rule" for judging protective coating systems . . . permitting quick, accurate evaluation of systems on the basis of cost per square foot per year of service. Write for your free copy today.



**carboline**  
C O M P A N Y

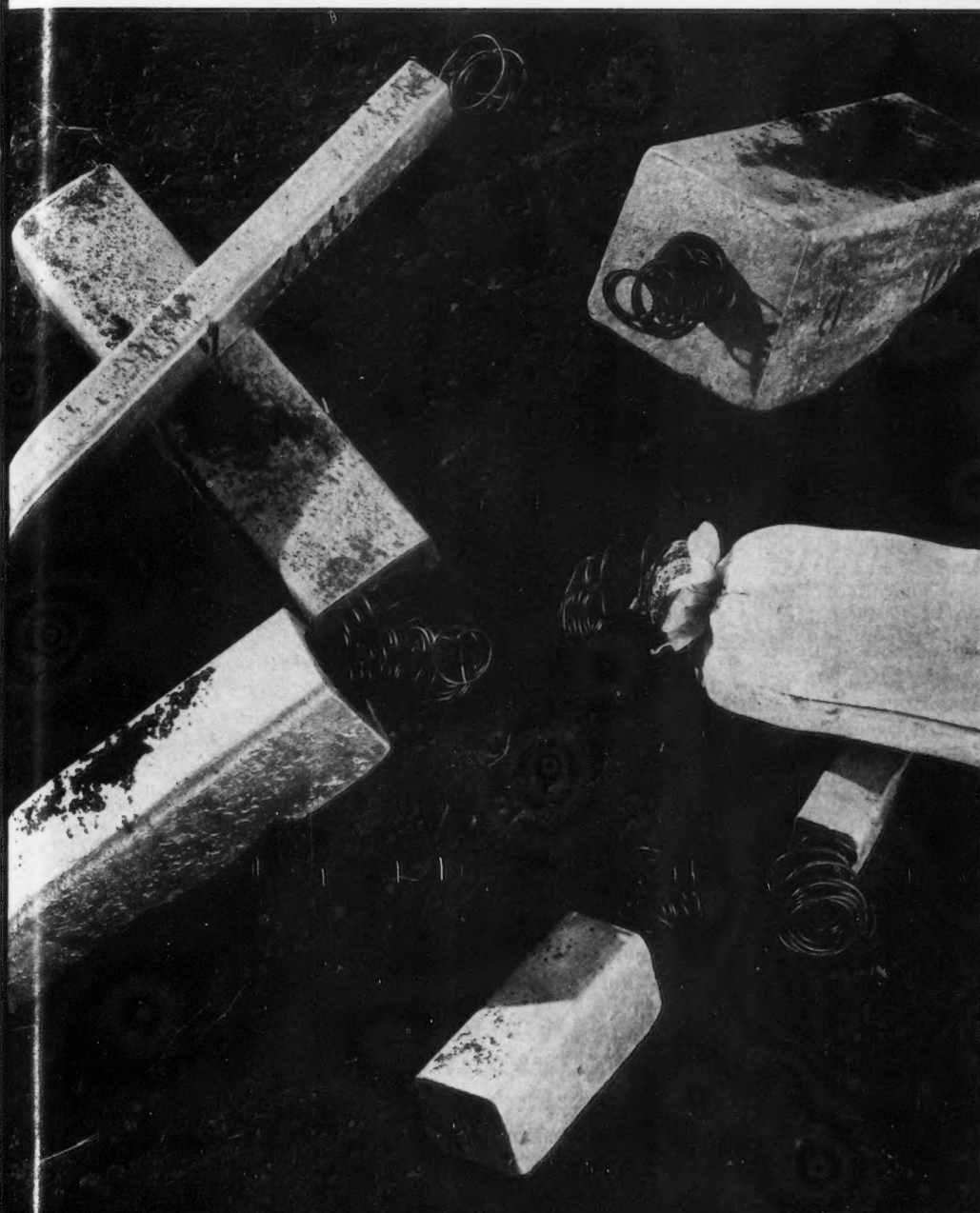
32-A Hanley Industrial Court  
St. Louis 17, Mo.

Manufacturers of  
PHENOLINE, POLYCLAD,  
RUSTBOND PRIMERS

*Specialists  
in Corrosion Resisting  
Coatings and Linings*

*No other supplier offers you as many materials* or as much practical experience in corrosion control. Federated's Corrosion Advisory Service can recommend the best for you from among GALVANIC ANODES, magnesium and zinc; LEAD SHEET, PIPE, and FITTINGS; ZINC and ZINC ALLOYS for galvanizing; ZINC DUST; COPPER and ALLOYS; and PLATING MATERIALS, including copper, lead, cadmium, zinc, and silver anodes; nickel salts and addition agents for plating baths. One of Federated's 22 sales offices is near you. Don't hesitate, call us with your corrosion problems . . . no obligation, of course. Federated Metals Division, 120 Broadway, New York 5. In Canada: Federated Metals Canada, Ltd., Toronto and Montreal.

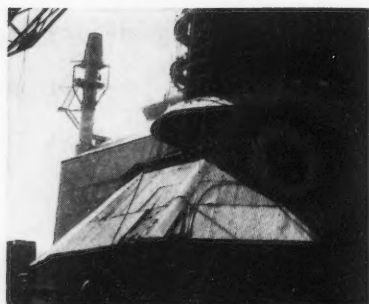
## FEDERATED METALS DIVISION OF



# ASAARCO

AMERICAN SMELTING AND REFINING COMPANY

## "METAL GRAY" ROOFING AND SIDING INERT TO CHEMICAL-LADEN AIR



These are "before and after" photographs of the roofing at base of a blast furnace, Pittsburgh, showing replacement of the old roofing with Resolite Metal Gray sheeting.

"Metal Gray" corrugated sheeting, for roofing and siding of industrial buildings where air-borne chemicals prevail, are virtually unaffected by these normally present chemicals. The sheeting is molded of fiberglass and polyester resins specially formulated for such use.

Where corrugated metal or mineral fiber quickly decompose under such chemical onslaught, Metal Gray sheeting, a Resolite product, will outlast these materials indefinitely.

Opaque and of neutral gray color, this sheeting is molded in all standard corrugations and in flat sheets. Standard sheet fastening methods are used for installation. Corrugated sheets are supplied in lengths up to 12 feet; flat sheets to 48" by 96".

Fire retardant Metal Gray sheeting is also available, using the famous Fire-Snuf formulation, and has a flame spread rating of below 35, as determined by experimental testing in an independent laboratory.

For complete Metal Gray information, including physical properties, chemical resistance, and loading data, write for Bulletin 581.



**RESOLITE CORPORATION**

Box 538, Zelienople, Pa.

Chicago • Atlanta • Houston • Toronto

## NEW PRODUCTS

(Continued From Page 100)

### Pumps

A Rotating Electrical field is used to drive a pump handling plating solution through a filter, Sel-Rex Corp., Nutley, N. J. developed the system which eliminates stuffing boxes and seals and maintains solution integrity.

### Tantalum, Platinum, Titanium

Kemet solid tantalum capacitors made by Kemet Co., Div. Union Carbide Corp., P. O. Box 6087, Cleveland 1, Ohio have high resistance to vibration and temperatures up to 125 C. They are available in a wide range of capacitances and are immune to humidity and salt spray.

Platinum-Clad tantalum expanded mesh anodes for rhodium electroplating are being made by Metals and Controls Corp., Attleboro, Mass.

Titanium Welding information is available from Titanium Metals Corp. of America, 233 Broadway, New York 7, N. Y. in its "Minute Reader No. 4" available on request.

### Valves

Nickel-Coated, Rockwell-Nordstrom lubricated plug valves are being made by Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.

### Zirconium

Technical and Application Data on Zirconium and Hafnium, a 16-page brochure published by Mallory-Sharon Metals Corp., Niles, Ohio discusses the properties of both metals in nuclear reactor applications and gives physical, mechanical and corrosion resistance data.

## MEN in the NEWS

Robert Bryson has been transferred by Tubular Lining Corp., to Lafayette,

## COKE BREEZE

### Backfill for Anodes

Ideally suited for use with anodes. Has a high carbon content and comes in sizes of  $\frac{1}{8}$ -inch x 0 to  $\frac{3}{8}$  x  $\frac{1}{8}$  inch. In bulk or sacks. Prices on other sizes on request.

**National Carbon Anodes**

**Magnesium Anodes**

**Good-All Rectifiers**

## WHOLESALE COKE COMPANY

PHONE GARDENDALE, ALA.  
HElock 6-3603

P. O. Box 94

Mr. Olive, Ala.

Louisiana as manager of the company's sales office there. He will cover all of southern Louisiana from his new location.

C. J. "Neil" McBride has been appointed sales manager for the East Texas-Northern Louisiana area for Tubular Lining Corp., applicators and compounders of plastic linings for oil field tubing. The firm has headquarters in Houston, Texas. Mr. McBride is a member of NACE.

Walter H. Daub, Jr. has been promoted to an assignment as sales development representative of Pittsburgh Coke & Chemical Company's Industrial Chemicals Division. He will be succeeded in the Philadelphia territory by Donald L. McCuen.

Edward H. Garnett of Pennsalt Chemicals Corp. will establish a new sales office for its corrosion engineering products in Kansas City, Missouri. His headquarters will be at 6317 Raytown Rd., Kansas City.

Herberth E. Head, Chrysler Corp. was elected president of the American Electroplaters' Society at the annual meeting May 22 in Cincinnati, Ohio.

Two scientists in executive positions with the National Bureau of Standards have been cited by another department of government, the U. S. Department of Commerce, for their work. Leroy L. Wyman received the meritorious service award for his original contributions to alloy theory and to the design and production of important ordnance items. John L. Hague was cited for outstanding original contributions to methods of analysis necessary for controlling the production of complex metal alloys.

Professor William D. Robertson has been appointed chairman of the department of metallurgy, Yale University, succeeding professor Arthur Phillips who will be on leave of absence preceding his retirement in June 1959.

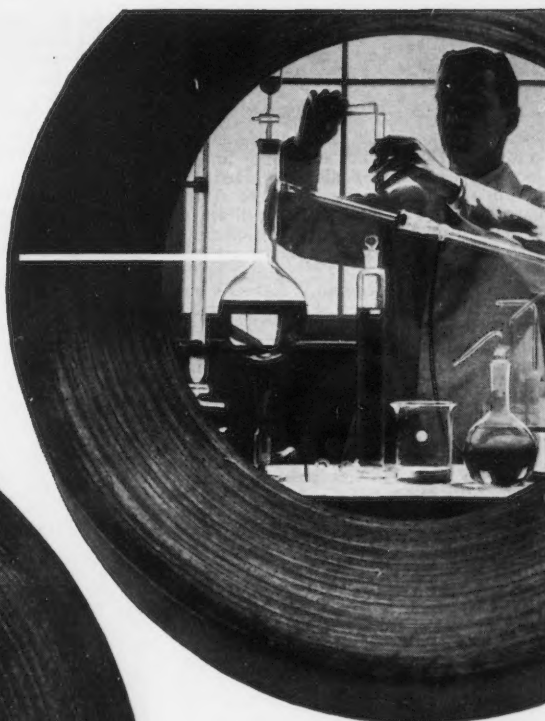
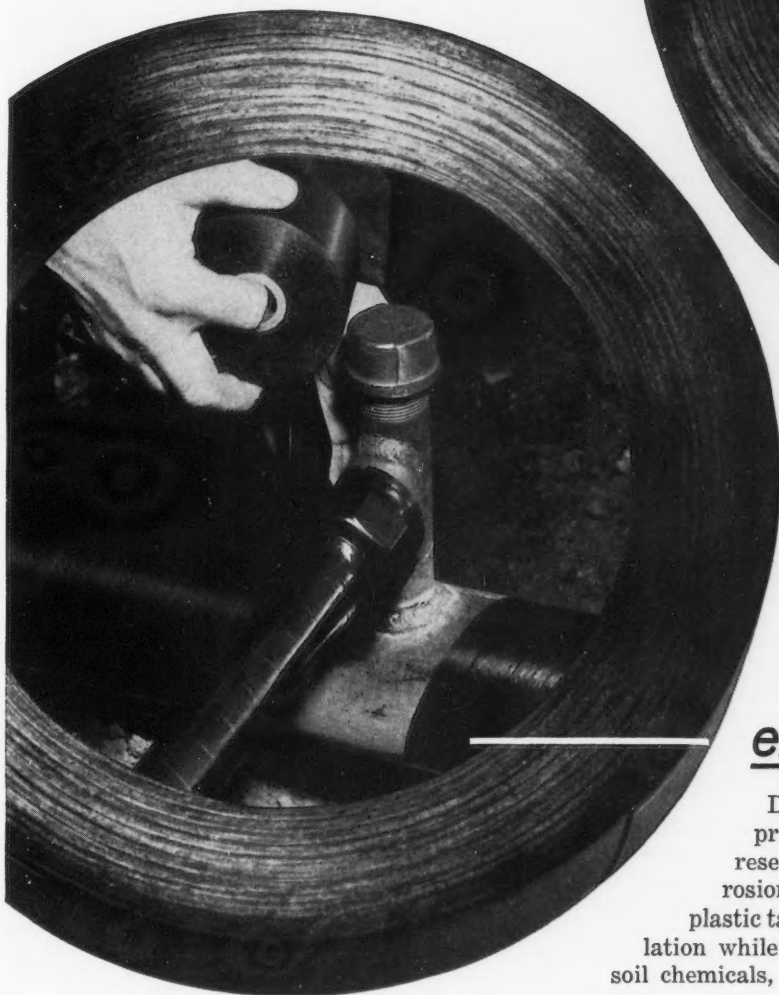
J. H. Cogshall has been appointed sales manager and Robert S. Mercer manager of development of Pennsalt Chemicals, Corp., Philadelphia. Both are in the corrosion engineering products department of their firm. Mr. Cogshall has held local and national committee assignments and is currently chairman of technical practices committee T-6R on Protective Coatings Research. He is also a member of six other technical committees. Mr. Mercer presently is vice chairman of the Philadelphia Section. He is the author of a number of corrosion papers, including "A New Inorganic Cement Mortar for Sulfuric Acid Service," presented at the NACE 14th Annual Conference in San Francisco last year. He also is a member of five NACE technical committees.

Carl M. Marberg, Jones Laughlin Steel Corp., Pittsburgh, has been appointed manager, technical services for the container division of the firm. Mr. Marberg has had considerable experience in research and teaching and is in several books listing prominent scientific men.

(Continued on Page 106)



*corrosion control*  
**with DRESSERTAPE®**  
*begins here*



*endures here*

Dressertape...the perfect pipeline protection... is the product of years of research and testing at the Dresser Corrosion Laboratories. This high dielectric plastic tape provides excellent electrical insulation while protecting underground pipe from soil chemicals, salt water, acids, alkalies, and oil.

Dressertape has high adhesive firmness, extra strength, sunlight resistance, and excellent aging qualities. In its narrower widths, it conforms perfectly to the contours of small diameter fittings and is ideal for service lines. You can also get it in widths up to 12-inches, and in thicknesses of 10-Mil or 20-Mil. Apply it cold—no pots, no fumes, no burns. The ditch can be backfilled immediately since no "setting up" period is required.

Send for Dressertape Booklet, form No. 548. It gives complete specifications, properties, and lists many additional benefits for *you*.

**DRESSER**

MANUFACTURING DIVISION



Bradford, Pennsylvania • Chicago • Houston  
 New York • Philadelphia • S. San Francisco  
 Toronto & Calgary

## MEN in the NEWS

(Continued From Page 104)

**Donald V. Sarbach** has been named director of new product development for Goodrich-Gulf Chemicals, Inc. He will set up a laboratory for the firm at its Institute, W. Va., plant which will serve customers in the development of new product applications.

**William Hunt Eisenman**, 73, secretary and a founder-member of the American Society for Metals, died May 30 in La-Jolla, Cal. Mr. Eisenman joined the American Society for Steel Treating, forerunner of ASM in 1918 as national secretary. He led the society from a one-desk organization with less than 200 members to more than 30,000.

**Robert W. Hanlon** has been promoted to superintendent, coke and by-products department of the Pittsburgh Coke and Chemical Co. The promotion was one of three prompted by a company consolidation.

**John G. Cumming** has been appointed manager of the southwestern division of the A. M. Byers Co., producers of wrought iron. He will make his headquarters in Houston.

**Gene Wedereit** has been promoted to the corporate staff as director of advertising and public relations for Chemetron Corp., formerly named National Cylinder Gas Co. Mr. Wedereit was formerly director of advertising for several of the company's divisions. He has been with the firm 15 years.

**Eugene Ransom** is now general manager of the industrial hose division, Flexonics Corp. Prior to his appointment, he was on special assignment at the firm's Memphis plant. The hose division is one of five established as part of the firm's new organizational plan. Other divisions are aircraft, bellows, expansion joint and automotive.

Appointment of **Frank S. Briggs** as manager of a newly established nuclear energy and power plant section of the sales development department of Tube Turns, Louisville, Ky., was announced recently. The company is a division of Chemetron Corp.

**Peter L. Shanta** has been appointed technical director of Taylor Fibre Co., Norristown, Pa. The firm manufactures laminated plastics and vulcanized fibre. Mr. Shanta will have charge of all research, product development and quality control activities of the company.

**Heinz V. Menking** has been named general director of product development for Reynolds Metals Co. Born in Hungary of German parents, he was for seven years associated with I. G. Farbenindustrie developing fabricating practices and new applications in the light metals field. He moved to the United States in 1932.

**Edward (Ned) A. Sargeant** has joined the sales organization of Robt. L. Rowan & Associates. He has had experience in chemical plant construction and is a sales engineer. The firm markets corrosion preventive materials and mechanical equipment.

**George H. Gustat**, director of the industrial engineering division, Kodak Park Works plant, Eastman Kodak Co. has been elected president of the American Institute of Industrial Engineers for 1958-59. He was scheduled to take office June 14. The society has 8,000 members.

**Jack D. Tolliver** has been appointed to the newly established position of sales manager for the Eastern region of Tube Turns, Louisville, Ky., division of Chemetron Corp. His sales operations will be covered from offices in New York, Philadelphia, Pittsburgh, Chicago, Louisville and Atlanta.

New national officers of the American Society for Testing Materials were scheduled for election last June. One of the nominees, **Frank L. LaQue**, was nominated to continue in the office of senior vice-president. Mr. LaQue is also a member of National Association of Corrosion Engineers and has long been prominent in NACE affairs, being active on various committees, and is a past president of the association.

ASTM nominees were: for president, **Keneth B. Woods**, head, school of civil engineering and director, joint highway research project, Purdue University; for vice-president, **A. Allan Bates**, vice-president of research and development, Portland Cement Association. Nominated for three-year terms on the ASTM board of directors were: **Paul A. Archibald**, chief metallurgist, Standard Steel Works Div., Baldwin-Lima-Hamilton Corp.; **William L. Find**, chief, physical metallurgy division, Alcoa Research Labs.; **Harry M. Hancock**, manager, product control department, Atlantic Refining Co.; **Lawrence A. O'Leary**, head, chemical engineering and research dept., W. P. Fuller & Co.; and **Alfred C. Webber**, senior supervisor, experimental station, E. I. duPont de Nemours & Co., Inc.

**A. R. Murdison** has been transferred from Toronto to Winnipeg where he will be affiliated with the Winnipeg Pipe Line Co., Ltd. Mr. Murdison is a member of National Association of Corrosion Engineers board of directors, representing the Canadian Region. He is also a member of the NACE Policy and Planning Committee.

**Oscar O. Miller** of The International Nickel Co., Inc., has been elected president of the Technical Societies Council of New Jersey, Inc. Date set for installation was June 9. The New Jersey society comprises 22 scientific, engineering and technical professional societies that have branches or members throughout New Jersey.

**George F. Murphy** has been named assistant chief construction engineer for Aluminum Company of America. A native of Pittsburgh, he has been manager of the company's general service division at Alcoa, Tenn. since 1946.

NACE member **W. F. Bliss, Jr.**, has been appointed technical sales representative at Houston for Geigy Industrial Chemicals Div., Geigy Chemical Corp. Other technical societies to which Mr. Bliss belongs are, ACS and the American Association for the Advancement of Science.

**W. Kent Kise, Jr.**, will assist in the

development of alloys for electronic, magnetic and electrical applications for the Carpenter Steel Co. He was appointed to the position recently.

**Noel S. Chamberlin** has been appointed manager of a new chemical process department formed by the Graver Water Conditioning Co. The department was formed to handle expanding program of liquid treatment applications.

**Arthur F. Smith** has become an associate in the firm of Chemical Manufacturing Co., New York. He formerly was assistant to the executive vice-president of Food Machinery & Chemical Corp.

**Richard Y. Moss** has been appointed manager of By-Products and Lukens-weld fabrication sales to succeed **Edmund Pfeifer**, who has been promoted to director of purchases in the Lukens Steel Co.

**Paul L. McCulloch, Jr.**, president of the Electro-Alloys Div., American Brake Shoe Co., Elyria, Ohio has been elected president of the Alloy Casting Institute for a one-year term.

**Thomas Courtney, Jr.**, design research specialist, has been named chief project engineer for Temco Aircraft Corp. The firm is engaged in aircraft, missile and electronics work.

**Edgar H. Dix, Jr.**, assistant director of research, Aluminum Company of America has been awarded an honorary degree of doctor of science by Carnegie Institute of Technology, Pittsburgh. Much of his work, particularly in the area of corrosion resistance has been in the development of aircraft alloys.

**F. R. Owens**, president, Cyrus William Rice & Co., Pittsburgh, has been awarded the 5th Max Hecht Award of the American Society for Testing Materials for outstanding service in the study of water as an engineering material. Max Hecht was the first chairman of ASTM D-19 on Industrial Water. Presentation of the award was at the ASTM 61st Annual Meeting.

**Robert N. Wagner** has been appointed chief electrical engineer for Aluminum Company of America, succeeding **Louis N. Grier** who retired July 1 after 39 years of service.

**William A. Baltzell** has been appointed industrial sales manager for Oakite Products, Inc. He will be responsible for the company's 17 divisions and 240 technical representatives in the U. S. and Canada. He formerly was assistant sales manager.

**Robert R. Pierce** has been named manager of the corrosion engineering products department of Pennsalt Chemicals Corp. He is his firm's corporate member representative to National Association of Corrosion Engineers, is past chairman of NACE Philadelphia Section, and an association director 1955-57. He is presently vice-chairman of the Inter Society Corrosion Committee. He is also a member of AIChE.

**Thomas J. McLeer** has rejoined the Cooper Alloy Corp. and will direct the research and development activities of the corporation. The firm is a corporate member of NACE.

# TECHNICAL TOPICS

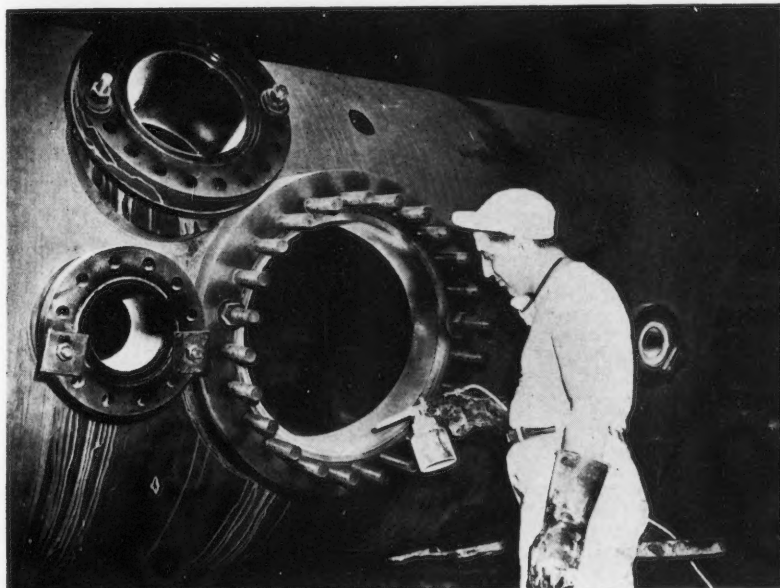


Figure 1—Operator is shown using the electrified particle inspection method on a process vessel.

## Electrified Particle Inspection Method Locates Defects in Non-Metallic Coatings\*

**I**NEXPENSIVE base structures coated with corrosion-resistant materials such as glass, plastic, silicone and epoxy-resins need to be checked periodically for defects.

The electrified particle inspection method,\* a new technique for inspecting non-conductive coatings on metal is used by many manufacturers of porcelain enameled goods, glass-to-metal seals and organic resin coated industrial equipment.

It works in the following manner: A specially selected powder is blown through a hard rubber nozzle of a special powder gun as shown in Figure 1. Electrons rub off as the particles pass through the gun nozzle, charging the powder positively (+). As the powder approaches the test piece, electrons are attracted from the base metal. Wherever a lower dielectric exists, such as at a pinhole or crack, electrons tend to bunch up in the metal and exert their influence through the defect. Since negative charges attract positive ones, the powder builds up over defects in the manner shown in Figures 2 and 3.

Several types of defects may occur in corrosion-resistant coatings. One type is called craze. This defect appears as an overall pattern with interconnecting cracks arranged in a somewhat decorative manner. Craze occurs when the co-

efficient of expansion of the glass is not properly matched to that of the base metal.

Manufacturers of glass-lined vessels rarely produce crazed coatings and the condition rarely exists in organic resin linings. The user of glass lined vessels may produce this condition by an accidental thermal shock to a vessel in service. When the possibility of crazing has occurred, but there is no visual evidence, this inspection method will help confirm or refute the suspicions of the user.

Another type of defect commonly observed on glass-coated equipment has been termed the roller coaster. This type of crack is usually a manufacturing de-

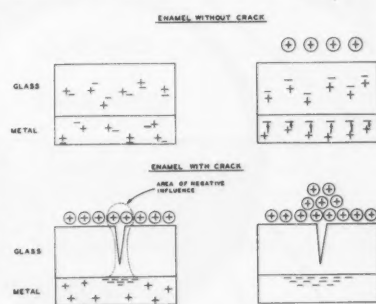


Figure 2—Schematic diagram showing electrical principles involved in electrified particle inspection method.

### Abstract

A method of locating minute cracks in glass, plastic, silicone and epoxy-resin coatings is described. When a specially selected powder is blown through a hard rubber nozzle, electrons rub off as the particles pass through the nozzle, giving the powder a positive charge. As the powder approaches the test piece, electrons are attracted from base metal. Wherever a lower dielectric exists, such as at a defect, electrons bunch up and attract the positively charged powder at sites over the defects.

When a defect goes through to metal a characteristic indication occurs. This is a pulsation produced by the building up and discharge of a positive potential on the surface of the coating. Defects measuring less than 4 millionths of an inch in width can be located by the method. 2.4.3

fect found in exceptionally thick coatings. The cracks may range from three to several hundred feet in length and tend to meander in distinctive roller coaster fashion, without crossing one another. Brine tests used in conjunction with the electrified particle inspection method have confirmed that this type of defect rarely, if ever, goes through to metal. Despite this, they should be treated as potential trouble makers.

The stress crack is most commonly found in glass and resin coatings. Stress cracks, usually invisible to the naked eye, occur in a plane perpendicular to the direction of applied stress at places of bolt up, changes of section, or where attachments have been welded in place. They indicate a physical disturbance produced by mechanical stress.

Stress cracks invariably go through to base metal at some point in their length and for this reason should be considered serious. They are especially dangerous because they expose the base metal to the corrosive material contained in the vessel in such way that an attack at this localized area will proceed without indications on the surface of the glass. The result may be, in glass lined equipment for example, the glass appears sound, while the metal below is almost completely corroded away.

Whenever a defect is completely through-to-metal, the electrified particle inspection method produces a peculiar indication, a "blink" or apparent pulsation during inspection. The blinking indication is produced by the building up of a positive potential on the surface of

(Continued on Page 108)

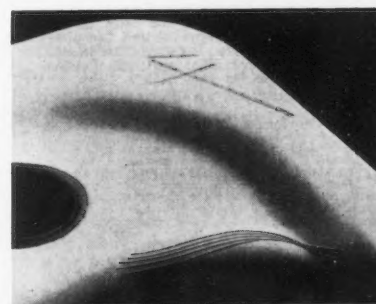


Figure 3—Typical indication of a defect in porcelain enamel as indicated by the electrified particle method.

\* By William E. Durack, Magnaflux Corp., Chicago, Ill.

\* Statiflux, developed by the Magnaflux Corporation of Chicago, Ill.



## Electrified Particle—

(Continued From Page 107)

the non-conductive coating. A corresponding negative potential builds up in the metallic layer. When the potential builds up high enough to break down the dielectric contained in the defect (which is air), an arc results. This arc neutralizes the attractive forces holding the powder in place and the indication is forcibly removed by new powder par-

ticles being sprayed from the gun. As additional powder is applied to the area, the cycle is repeated. The build-up and removal of indication occurs so rapidly that it appears as if it is pulsating or blinking. When a length of crack is broken through, a series of round indications appear along the defect and blink at random. This effect occurs only as the powder is being applied to the surface.

This method greatly assists in the location and interpretation of defects in coatings, particularly because it produces indication up to 30,000 times larger than the actual width of the defect. The method is so sensitive that it is possible to locate defects less than 4 millionths of an inch in width. A defect this wide occurring in transparent material is completely invisible.

The electrified particle inspection method has been criticized for its extreme sensitivity on the premise that something that couldn't be seen, couldn't possibly be injurious. In practice this notion has consistently been disproved because the defect can be injurious regardless of its width if metal is exposed.

Accurate delineation of defects in coatings can help both the designer and user of coated equipment. A crack is an indication of a stress present at some time before actual formation of the defect. Also, because a crack always forms in a direction perpendicular to the direction of principal stress the electrified particle inspection method locates not only defects but their cause, too.

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## PERIODICALS

**Nuclear Technology Briefs—Reactor Materials.** 15 pages, 8x10½ inches, typescript. March, 1958. United States Atomic Energy Commission, Washington 25, D.C.

Discusses the uses of niobium and of plutonium as a reactor fuel.

## Metallurgical Society

The Metallurgical Society, a component of the American Institute of Mining, Metallurgical and Petroleum Engineers will hold its fall meeting October 27-30 at the Carter Hotel, Cleveland during the Metal Congress. The Titanium and Nuclear Metallurgy Committees are among those which will sponsor symposia.

## Packaging Exhibition

A permanent packaging exhibition has been opened at 50 Poland St., in the center of London, England. The center will have a library and lounge.

## Air Pollution Congress

The Second International Congress on Air Pollution has been postponed to September 9-10, 1959.

South Central Region's 1958 Conference and Exhibition will be held October 20-24 at the Roosevelt Hotel, New Orleans.

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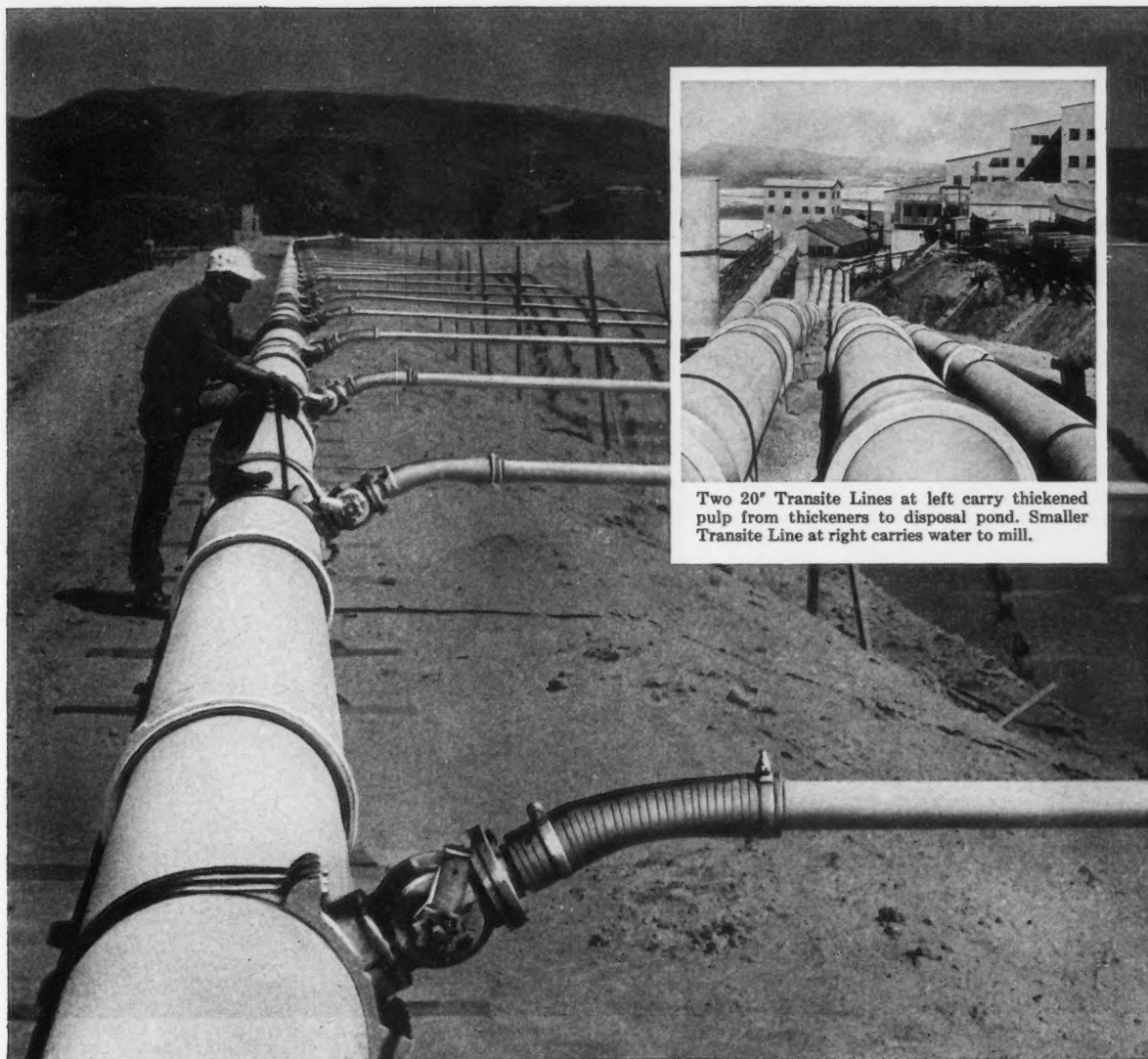
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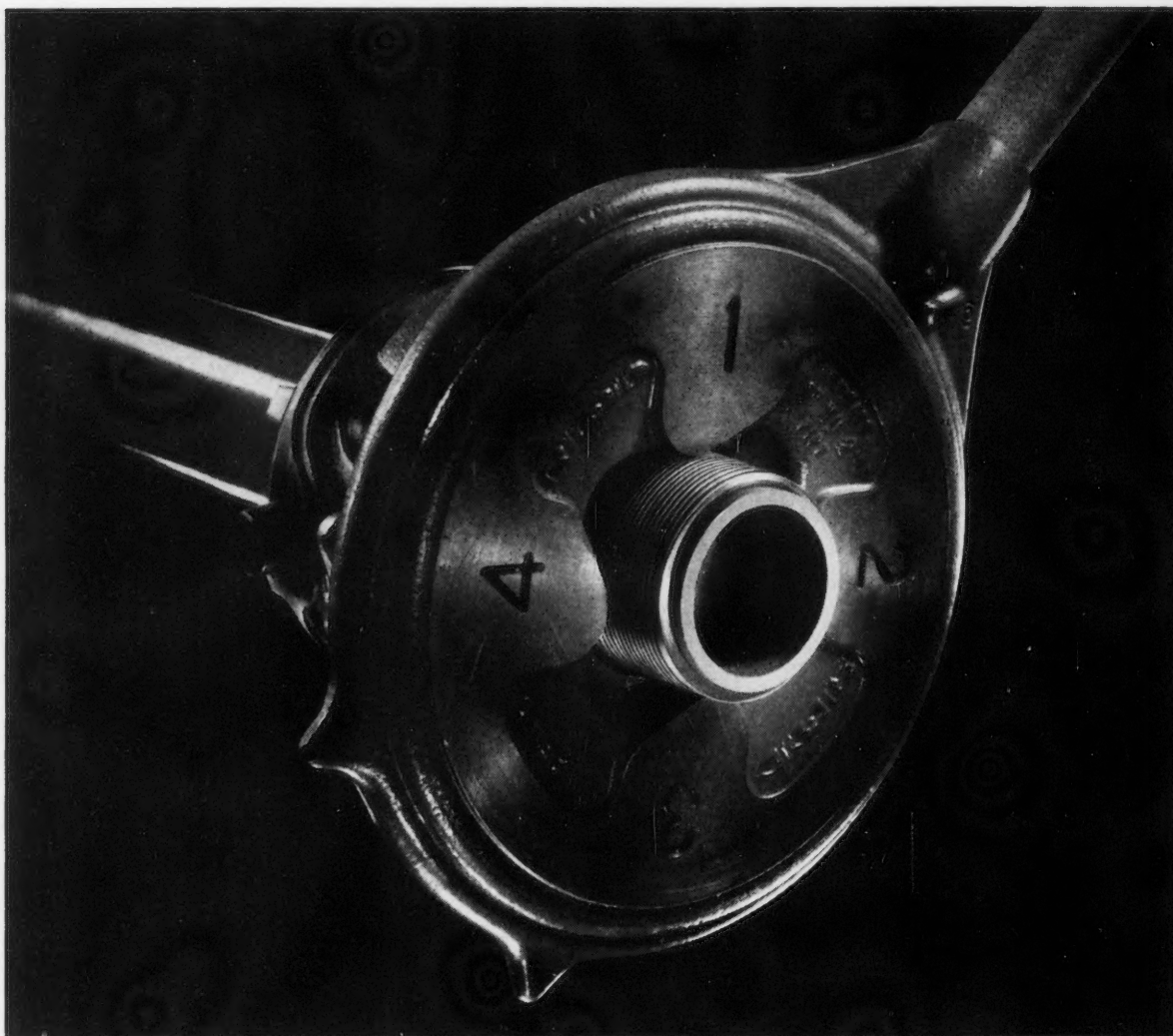
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# CORROSION ABSTRACTS

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Vol. 14 August, 1958 No. 8

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### 2. TESTING

#### 2.3 Laboratory Methods and Tests

##### 2.3.6, 3.7.3

Etching Technique for Simultaneous Development of Austenite and Pearlite Structures. V. S. POPOV. *Factory Lab. (Zavodskaya Laboratoriya)*, 22, No. 3, 317 (1956).

Currently used etching technique for welds joining an austenitic steel with a pearlitic one and involving marked over-etching of the latter. New etching technique permitting simultaneous development of austenitic and pearlitic structures in composite welds, clad steel, etc. Translation available: Henry Brucher, P. O. Box 157, Altadena, California. 13686

##### 2.3.7

Effects of Specimen Preparation on Fatigue. F. H. VITOVEC AND H. F. BINDER. University of Minnesota. U. S. Wright Air Development Center, August, 1956, 53 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C. (Order PB 121576).

Many studies have been made on the effects of surface preparation methods for plain alloy specimens on fatigue properties. Those effects are reviewed in this report, with emphasis on machining, grinding and mechanical and electrolytic polishing. Little work had been done, however, on the effect of specimen methods on the fatigue properties of notched specimens. An investigation was conducted of the penetration of plastic deformation caused by the notch preparation. Data is reported on the effect of lapping procedure on the Prot failure stress of SAE B1113 steel and SAE 1020 steel. It was found that the direct stress fatigue properties of notched

specimens were not affected by the direction of lapping. The amount of material removed in the lapping process had no significant effect on the fatigue properties of the steels. 13727

##### 2.3.7

Influence of External Energy on Brittleness in Bend Tests. A. ALMAR-NAESS. *Brit. Welding J.*, 4, No. 2 (1957) Feb.; *Welding Research Abroad*, 3, No. 3, 48-57 (1957) May.

Whereas many investigators have shown that internal energy released during crack propagation is the maintaining force of brittle fracture, this report shows that in a bend specimen, external energy released from testing equipment has same effect qualitatively. When transition temperature of material defined by 50% brittle area is found by notched-bend specimens, result is influenced by response of testing machine, a soft machine giving a higher transition temperature than a stiff one. Similar influence is expected for notched tensile test. Results are given of bend specimens with increased external or internal energy and of specimens bent in loading jig whereby internal energy was limited by preventing arms from bending. Specimens were of 1¼-in. thick mild steel (0.08 nickel) ship plate. Diagrams, graphs, tables.—INCO. 14211

##### 2.3.7

Further Studies of an Electronic Thickness Gage: Circuitry Operating Characteristics, and Calibration. F. P. BRODELL AND A. BRENNER. *Plating*, 44, No. 6, 591-601 (1957) June.

Electronic thickness gage, previously developed for measuring metallic coatings on nonmagnetic basis metals, was improved by using circuit bridge and by designing gage head so that an adjustment of it—"peaking"—could be performed conveniently. Because peaking is important for obtaining reproducible results, curvature and nature of basis metal and capacitance across probe coil were studied as factors that affect peaking. Study was made of calibrations of Dermatron for several combinations of coatings and basis metals. Thickness of nickel coatings selected at random cannot be accurately measured and Dermatron is not recommended except under restricted conditions. Measurements of poorly conductive and nonconductive coatings require different technique; preferably with probe coil off peak. Graphs include calibration curves for silver on nickel silver, copper on steel, nickel on steel and nickel on brass; and effect of tensile stress in nickel on Dermatron gage readings.—INCO. 14263

##### 2.3.7, 3.2.2

Determining Inter-Crystalline Corrosion by Measuring Internal Friction. (In Russian.) M. A. VEDENEVA, A. V. PANOV AND N. D. TOMASHOV. *Zavodskaya Laboratoriia* (Factory Lab.), 23, 64-67 (1957) Jan.

The degree of internal friction is obtained by setting up transverse vibrations in the specimen and obtaining their resonance curves.—BTR. 14168

##### 2.3.7, 3.5.8

A New Detection of Fatigue Damage in Metals. A. J. KENNEDY. *Nature*, 179, No. 4573, 1291-1292 (1957) June 22.

Description of experiment on whether a potentially dangerous state of fatigue may be detected earlier in the life before metal is heavily damaged. Experiments were conducted on lead wires maintained at constant temperature in an apparatus which can apply a longitudinal fatigue stress or a torsional creep stress or both simultaneously. Results of five tests are discussed. Graph, table.—INCO. 14280

##### 2.3.7, 6.6.8, 3.5.8

Environmental Stress Cracking of Ethylene Plastic. K. A. KAUFMANN. *Modern Plastics*, 34, No. 6, 146, 148, 232 (1957) Feb.

The phenomenon is recognized as one of several limitations of polyethylene. Proposed ASTM test method is outlined and discussed.—BL. 13792

##### 2.3.7

An Instrument for Determining the Condition of a Surface Coating. HOWARD R. MOORE AND JAMES R. JENNESS, JR. *Paint Ind. Mag.*, 72, 16, 18 (1957) Jan.

The rolling friction acting as a steel

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ball which rolls over a coated surface is determined, and the ratio between the coefficient of rolling friction and the radius of the test ball serves as a dimensionless index of surface condition.—BTR. 13788



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### 2.3.7

**A Method of Measuring the Adhesion of Organic Coatings to Metals.** W. D. MAY, N. D. P. SMITH AND C. I. SNOW. *Nature*, 179, No. 4557, 494 (1957) March 2.

Method enables adhesion to be distinguished from mechanical properties of coatings and may be used to study effects of various atmospheric and other conditions on adhesion. Procedure consists of decelerating coated metal from a high velocity in such a way as to apply a force to coating which causes it to fly off metal surface. A 'bullet' in form of a thin steel disk, punched from a panel coated with substance under test and with an annulus of coating removed so as to leave a spot of coating in center, is fired from an air gun at a hard steel target having a hole in line with coated spot of 'bullet.' Coating is decelerated by force generated when 'bullet' is stopped and if force is high enough, becomes detached by its own momentum. By firing 'bullets' at different velocities, threshold velocity at which coating becomes detached can be determined.—INCO. 13785

### 2.3.7, 6.6.8

**Accelerated Fatigue of Plastics.** L. S. LAZAR. *A.S.T.M. Bull.*, No. 220, 67-72 (1957) Feb.

An appraisal of the validity of Prot progressive loading method using plastics under rotating and nonrotating fatigue conditions.—BL. 13824

### 2.3.7, 6.3.15, 3.7.3

**Stress Corrosion of Titanium Weldments.** RUSSEL MEREDITH AND W. L. ARTER. *Welding J.*, 36, 415s-418s (1957) Sept.

The cause of weld cracking at high

temperature in a resistance and fusion-welded tank of RC-A110AT was investigated. Physical testing included hydrostatic pressure testing and tension-compression loading parallel to the longitudinal axis at 270 F, and hydrostatic testing at 700 F using a chlorinated hydrocarbon as a pressurizing medium. In the latter test numerous transverse weld cracks developed in both kinds of welds. The cause was attributed to free hydrochloric acid in the hydrocarbon, although the mechanism is uncertain.—MR. 14824

### 2.3.9, 3.2.3

**Kinetic Study of Structural Transformations and Oxidation Phenomena Observed by Electron Diffraction. The Significance of Using Various Pressures.** (In French.) J. J. TRILLAT. Communication presented to the Journées Metallurgiques d'Automne de la Société Française de Metallurgie, Paris, October 27, 1955. *Rev. Met.*, 53, No. 7, 497-502 (1956) July.

Principles of the continuous recording of electron diffraction patterns are discussed and the technical installation for that purpose is described. The method is said to allow the study of kinetics of structural transformations as a function of temperature and, by using during these researches various gas pressures, it is furthermore possible to study in particular the behavior of metals according to the oxygen content and therefore to follow the equilibrium reactions of oxidation of pure metals and alloys. Examples are given.—ALL. 12627

## 3. CHARACTERISTIC CORROSION PHENOMENA

### 3.2 Forms

#### 3.2.2, 3.2.2, 3.7.3

**Investigation of Intercrystalline Corrosion in Welded and Unwelded Nickel-Chromium Steels.** (In German.) H. ZITTER. *Arch. Eisenhüttenw.*, 28, 401-416 (1957) July.

Comparison of different test methods for determination of intercrystalline corrosion. Isothermal precipitation of grain boundary carbides is discussed. Differences were observed on testing in nitric acid-hydrofluoric acid, copper sulfate-sulfuric acid, nitric acid and oxalic acid test solutions. Thermal stresses during welding are described. Analysis was made of thermal energy distribution during arc welding, comparing ferritic and austenitic materials. Effect of welding speed on susceptibility to intercrystalline corrosion is given.—INCO. 14831

#### 3.2.2, 3.5.5, 6.3.20

**Thermal Diffusion of Hydrogen in Zirconium (Preliminary Report).** J. M. MARKOWITZ AND J. BELLE. Westinghouse Electric Corp. U. S. Atomic Energy Com. Pubn., WAPD-TM-42, Feb., 1957, 21 pp. Available from Office of Technical Services, Washington, D. C.

To explain the unusual corrosion failures of the Zircaloy-2 cladding in the X-1-h and X-1-g irradiation specimens, a mechanism was proposed which requires that hydrogen is introduced into the Zircaloy cladding at the internal surface. Ordinarily, the hydrogen should remain in the neighborhood of the interior surface. However, metallographic examination of the cladding showed that the highest concentration of hydrogen was actually near the exterior surface; in some instances, concentrations at this



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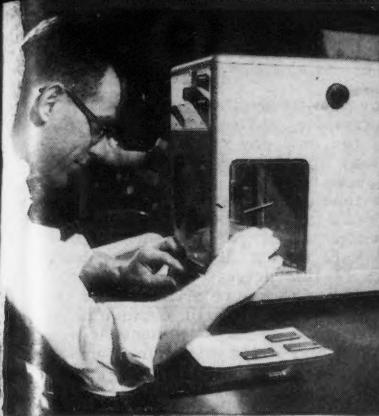


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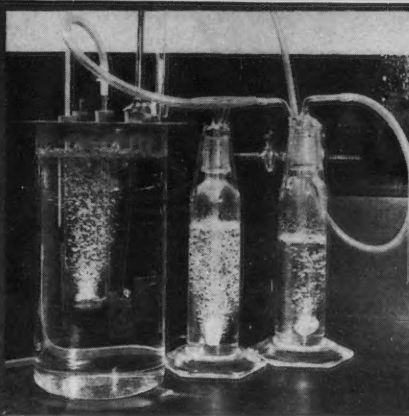
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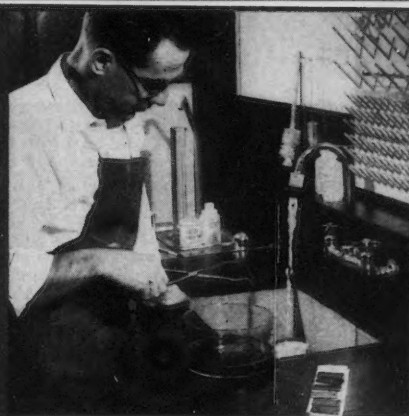
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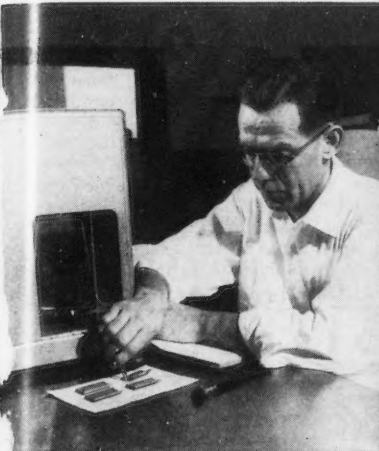
**1** Analytical weighing of specimens prior to testing



**2** Steam condensate corrosion test



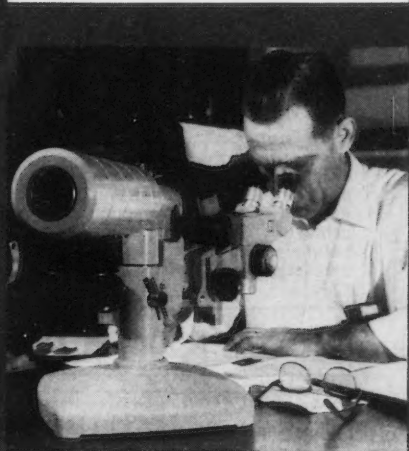
**3** Cleaning specimens with inhibited hydrochloric acid



**4** Second analytical weighing to determine corrosion weight loss



**5** Calculation and statistical analysis of laboratory test results



**6** Final examination of specimens under low power magnification

## Extensive testing program proves new 4-D Wrought Iron more corrosion-resistant than ferrous substitutes

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Tests	4-D Wrought Iron	Standard Wrought Iron	Ferrous Substitutes
Severe industrial atmospheric continued exposure 17 years	Corrosion weight loss 540 grams/sq. ft.	Corrosion weight loss 655 grams/sq. ft.	Not included in test
Steam condensate return line	*At least 25% greater corrosion-resistance than standard Wrought Iron	No failures 10 years (still in service)	Complete failure after 2 years
Aerated salt water—5 weeks (Short term test—points indicate 4-D Wrought Iron curve flattening out at much lower rate of attack)	Corrosion weight loss 146 mg/sq. in.	Corrosion weight loss 170 mg/sq. in.	Corrosion wt. loss 226 mg/sq. in.
Brine piping	*At least 25% greater corrosion-resistance than standard Wrought Iron	No failures 23 years (still in service)	Complete failure after 7 years
Salt water, Gulf of Mexico ¼ inch plate—17 years	Corrosion weight loss 4 mils./years (minimum plate thickness now 3/16") Still in excellent condition	Not included in test	Corrosion weight loss 30 mils./years; plate badly pitted, perforated
Downspout	*At least 25% greater corrosion-resistance than standard Wrought Iron	No failures in 29 years (Still in service)	Complete failure after 18 years

\*In this application no long term test data yet available on 4-D Wrought Iron. Results shown are derived from short term tests.



surface were large enough to produce hydride precipitation. Since the temperatures of the interior and exterior surfaces of the cladding were considerably different, it was proposed as part of the over-all mechanism that hydrogen is transported through the Zircaloy-2 from the interior to the exterior surface of the cladding by the process of thermal diffusion. This report is both a summary of preliminary studies on this problem and a proposal to extend the investigation. (auth)—NSA. 14723

### 3.2.3, 6.3.20

**A Study of the Oxidation in Air of Kroll Zirconium in the Heated State.** (In French.) JEAN HERENGUEL, DONALD WITTHAM AND JACQUES BOGHEN. *Compt. Rend.*, 243, 2060-2063 (1956) Dec. 17.

The known phenomenon of the oxidation in air of Kroll zirconium in the heated state, resulting in various volume increases of the sample depending on the temperature and sample thickness, may be explained by the fact that the resistance of zirconium to flow decreases considerably above 400-500 C and that the transformation of zirconium into the oxide is accompanied by a volume increase of about 50%. It is indicated that generally the self protection of a metal, achieved by a layer formed when the volume is increased, ceases in the temperature range of viscous deformation.

To increase this self protection attempts should be made to increase the resistance of the metal to flow or to render the protecting layer more viscous. 1 reference.—MR. 13569

### 3.4 Chemical Effects

#### 3.4.9, 3.4.3, 6.2.2

**Solubility and the Products of Reaction Between Iron and Water at 26 C and 300 C (Final Report).** V. J. LINNENBOM, J. I. HOOVER AND H. S. DREYER. Naval Research Lab., Washington, D. C., August 7, 1956, 15 pp. Available from Office of Technical Services, Washington, D. C. (Order PB 121409).

The iron content of saturated solutions resulting from the iron-water reaction in the absence of oxygen was obtained at 300 C using a radioactive tracer technique and at 26 C by spectrophotometric analysis. In both methods it was found necessary to filter the solution to remove undissolved solids. In addition, in the 300 C experiments, reproducibility of results was obtained only when the sample of saturated solution was separated from undissolved solid at the temperature and pressure of the experiment and the sampling process did not disturb the equilibrium between solid and saturated solution by

changes in temperature or pressure during sampling. After an initial increase over the first day or two, the concentrations of soluble iron species at both temperatures were found to decrease with time. This was presumably due to increased filtering efficiency as the colloidal undissolved particles increased in size with ageing. However, the possibility of this decrease being due to a change in the nature of the solute species with time was not eliminated. At 300 C, after 23 days' contact between the iron and water, the iron concentration appeared to approach a lower limit of 0.05 ppm iron and the only product of reaction found was magnetite,  $Fe_3O_4$ . Experiments at room temperature in the absence of oxygen indicate that the primary product of the reaction is ferrous hydroxide. After four days' contact between iron and water, a solubility value of 0.41 ppm iron was found; after 42 days' contact, this had decreased to 0.08 ppm iron. No  $Fe_3O_4$  was found when the reaction took place at room temperature; appearance of  $Fe_3O_4$  in the system was first found at temperatures between 50 and 60 C. The soluble iron concentration at 60 C was found to be 0.008 ppm iron after 10 days contact between iron and water. Although the project was terminated before sufficient data had been obtained to form any conclu-

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sions as to the reaction mechanisms, the results suggest other lines of attack which might further clarify the general problem of corrosion of iron in aqueous media, which is of particular interest in reactor technology. (auth).—NSA. 13434

### 3.5 Physical and Mechanical Effects

#### 3.5.9, 6.2.2

On the Oxidation of Iron in Air Between 400°-700° C. (In French.) J. PARISSI. *Acta Metallurgica*, 4, 227-229 (1956) March.

A letter.

14164

#### 3.5.9, 6.2.2, 3.4.6

An Investigation into the Catastrophic Corrosion of a Flake Graphite Cast Iron in Carbon Dioxide Containing a Small Amount of Carbon Monoxide. S. R. HILLINGTON AND B. C. WOODFINE. *Metallography*, 55, No. 331, 213-220 (1957) May.

A pearlitic flake graphite cast iron underwent severe oxidation in times of less than 3000 hours in a carbon monoxide-carbon dioxide equilibrium mixture under pressure of 200 psig at 525 C. Oxidation behavior of iron in both carbon dioxide and carbon monoxide-carbon dioxide mixtures at temperatures up to 525 C is described and a mechanism is suggested to account for the observed phenomena. Graphs, photomicrographs, table.—INCO. 14188

#### 3.5.9, 6.5

Investigation of the Compressive, Bearing and Shear Creep-Rupture Properties of Aircraft Structural Metals and Joints at Elevated Temperatures. F. J. VAWTER AND OTHERS. Cornell Aeronautical Laboratory, Inc. U. S. Wright Air Development Center Pubn., Sept., 1956, 95 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C. (Order PB 121656).

The shear, bearing and compressive creep behavior of aircraft structural materials as well as their tensile-creep behavior are believed to be important design criteria, particularly if stresses other than tension are to be encountered. This interim report supplements existing tensile-creep and rupture data by summarizing high-temperature creep data of aircraft sheet, plate and rivet structural alloys under the influence of shear bearing and compressive stresses. Tensile creep data are presented on A-70 commercially pure titanium, C-110M titanium alloy and SAE 4130 alloy steel sheet. Bearing creep data are listed for A-70 commercially pure titanium, C-110M titanium, 4130 steel and Type 321 stainless steel. Also, rupture stress data from shear-pin deformation tests are included for 2117-T4 aluminum, Monel and type 301 stainless steel wire, along with compression creep data for 2024-T3 aluminum sheet and plate and C-110M titanium. 14023

#### 3.5.9, 6.5, 3.5.8

Fatigue, Creep and Rupture Properties of Heat Resistant Materials. F. H. VITOVEC AND B. J. LAZAN. University of Minnesota. U. S. Wright Air Development Center Pubn., August, 1956, 213 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C. (Order PB 121580).

To aid in the search for jet aircraft compressor and turbine component materials that will resist creep, stress-rupture and fatigue at elevated temperatures, results of tests for these properties are summarized for the heat resistant



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Creep and fatigue as design factors and the relation of notch sensitivity to loading conditions are discussed with particular reference to temperature and ratio of alternating-to-mean stress. 13929

### 3.5.9, 6.6.6

**Kinetics of Oxidation of Iron Silicide in an Atmosphere of Air, at High Temperature.** (In Russian.) V. V. IPAT'EV AND G. M. ORLOVA. *J. Applied Chem., USSR* (Zhur. Priklad. Khim.), 29, No. 6, 811-818 (1956) June.

Oxidation of FeSi at 700, 800, 920 and 1000 C shows two periods. Temperature relation of oxidation rate. Correlation between oxidation-rate constant and structure of the scale; ratio of the thickness of Wustite and fayalite layers formed.—BTR. 14002

## 3.7 Metallurgical Effects

### 3.7.3, 6.2.3

**The Brittle Fracture Strength of Welded Steel Plates.** A. A. WELLS. Paper before Inst. Naval Architects, Spring Mtg., London, March 22, 1956. *Welding Research Abroad*, 3, No. 1, 9-24; disc., 25-39 (1957) Jan.

Describes series of tensile tests on mild steel plates 1 in. thick, where plates contained central, notched butt welds parallel to direction of pull. Notches were fine, shallow sawcuts made in plate edges prepared for welding, intended to simulate welding flaws. Tests were conducted at  $\pm 15$  C (below fracture transition temperature of parent metal). Fracture characteristics, influence of residual stresses, release of strain energy during propagation, and surface energy of material are considered. Above 4 C, plates sustained yield point average static tensile stresses before brittle fracture occurred. Below 4 C brittle fractures across weld residual stress zones started from sawcuts. At 4 C single stage fracture was produced at half yield point stress. In further tests between  $\pm 4$  C no residual stress zone fractures were produced at less than yield point stress in welded plates stress relieved by stretching at 40 C. Charpy V-notch energy of 7 ft. lb. at temperature at which alone complete fracture is obtained at half yield stress, matches energy range identified for casualties in American welded ships. Graphs, 20 references and lengthy discussions by 16 persons.—INCO. 14819

### 3.7.3, 6.2.5

**The Problem of Embrittlement in the Welding of Austenitic Heat-Resisting Steels.** H. F. TREMLER. Paper before I.I.W., Ann. Assembly, Essen, Germany. *Brit. Welding J.*, 4, No. 6, 283-287 (1957) June.

Formation of sigma phase in parent steel (23.7-25.9 chromium, 11.5-19.4 nickel) at 700 and 900 C is reviewed and embrittlement in heat-affected zone considered. Relationship between composition and weld metal constitution 'as-deposited' and at 900 C was studied for wide range of commercial electrodes including: 18/8/silicon, 18/8/niobium, 18/13/molybdenum, 23/11/3 tungsten, 25/17/silicon, 23/15/molybdenum, 23/13/niobium, and 25/20/silicon. Sigma phase is shown to form from duplex and full austenitic welds at 900 C. Degree of embrittlement is related to amount of carbide plus sigma phase; this is calculated from composition. Silicon is shown to be harmful. Suggestions are made to mitigate problem of hot crack susceptibility

of non-embrittling austenitic weld metal. Proposed plate and weld compositions, based on 0.4-0.8 silicon content, are given for minimum embrittlement and minimum nickel content. Constitution diagrams, tables.—INCO. 14828

### 3.7.3, 6.3.20

**Corrosion Resistance of Zircaloy-2 Brazements in High-Temperature Water.** J. B. McANDREW, H. SCHWARTZBART AND R. NECHLES. Paper before Am. Welding Society, Nat'l. Spr. Mtg., Philadelphia, April 8-12, 1957. *Welding J.*, 36, No. 6, 287s-290s (1957) June.

Brazements of simple geometry with Zircaloy-2 base metal were subjected to corrosion test in pressurized water at 680 F for periods up to and over 1200 hours. Alloys of silver, aluminum, copper, nickel, palladium, zirconium and gold were tested. Nickel-6 phosphorus filler metal was unattacked during test lasting 3379 hours. Palladium base alloys not only exhibited corrosion in braze proper but caused attack of adjacent base metal. Corrosion resistance was quite good for brazements prepared with following alloys: nickel-20 palladium-10 silicon, nickel-30 germanium-13 chromium, nickel-40 indium, copper-20 palladium-3 indium, zirconium-5 beryllium, and zirconium-10 iron-10 chromium.—INCO. 14311

### 3.7.3, 6.4.2, 1.6

**On the Precipitation Hardening of Aluminium-Copper Alloys.** (In German.) HERMANN FRANZ. Book, 1957, 156 pp. Aluminium-Verlag GMBH, Düsseldorf, Germany.

The author of this book has set himself the task of collecting, coordinating and comparing all the significant experimental and theoretical material hitherto published on the precipitation-hardening of aluminum alloys, aluminum-copper alloys, in particular, and, hence, to draw conclusions corresponding to our present-day knowledge on the subject. Accordingly, the author pursues a logical pattern by starting with investigations on the microstructure which is followed by tests on changes in mechanical, electric, magnetic, thermal and corrosive properties, together with studies of reversibility and the effect of deformation prior to heat treatment. In the subsequent theoretical part of the phenomenon is treated from the viewpoint of thermodynamics, energetics and kinetics. The author indicates that his primary object was completeness. It can be said that in this respect, and in many others as well, the book may be considered a very valuable addition to the existing literature.—ALL. 14627

### 3.7.3

**Corrosion Resistance of No. 20 and No. 20Cb Stainless-Steel Welds.** HALLOCK C. CAMPBELL, THOMAS J. MOORE AND S. E. TYSON. *Welding J.*, 36, 353s-359s (1957) August.

Both types become highly susceptible to intergranular corrosive attack after exposure to 1350 F for only two minutes. Annealing appears to be accomplished by heating to 1700 F for two hours, followed by a water quench. When there is danger of weld cracking, No. 20 electrodes should be used, but the vessel must be heat treated to prepare it for corrosive service.—BTR. 14609

### 3.7.3, 6.2.5

**How to Avoid Trouble with Stainless Welds.** G. E. LINNERT. Armco Steel



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Corp. *Steel*, 140, No. 25, 116-119 (1957) June 24; *ibid.*, 141, No. 1, 70-72 (1957) July 1.

Discusses cracks and failures caused by combination of hidden notches, stress concentrations and corrosion with stress and surface contaminants. Some causes of notch effects include unfused notches, undercutting along edge of weld beads,

flat and convex fillet beads, excessive weld bead reinforcement and bad design. Intergranular corrosion, occurring in sensitized stainless where carbides have precipitated in grain boundaries, is avoided by annealing, stabilization with niobium, niobium-tantalum or titanium, and use of extra low carbon grades. Stress relieving and use of ferrite types avoid stress corrosion cracking. In considering surface contaminants, effects of zinc and sulfur are discussed in detail. Precautions include removal of soaps, paint, marking pencils, soldering fluxes and cleaners which contain contaminants. Photographs and micrographs illustrate various defects.—INCO. 14699

### 3.7.3

**The Influence of Weld Faults on Fatigue Strength with Reference to Butt Joints in Pipe Lines.** R. P. NEWMAN. *Welding Research Abroad*, 3, No. 2, 9-28 (1957) March.

Fatigue tests were carried out on lengths of 6-in. diameter mild steel pipe containing welded butt joints. Condition of testing was alternating plane bending, developing stresses transverse to joint. Possible effects of weld faults were studied, as fatigue stressing is most critical condition for revealing such defects. Control data were established for different types of good quality welds (oxyacetylene, metal arc with and without backing ring). Data for comparison were obtained from defective joints with following faults: scattered porosity, tramlane slag inclusions, gross defects, lack of fusion, lack of penetration and piping or wormholes. For conditions applied, root zone of welds, with and without backing rings, exercises predominant influence on fatigue behavior. Except in case of lack of penetration, defects had no significant effect on fatigue strength because of overriding influence of root zone. Tables, graphs, radiographs and photomicrographs.—INCO. 13802

### 3.7.3, 6.4.2

**Hydrogen vs. Acetylene vs. Inert Gas in Welding Aluminum Alloys.** J. KOZI-

ARSKI. *Vertol Aircraft Corp. Welding J.*, 36, No. 2, 141-148 (1957) Feb.

Deals with porosity in heat affected zone and fusion and their possible effects on properties of welded joints in aluminum alloys made by oxyhydrogen, oxyacetylene and inert-gas tungsten-arc welding processes. Limited number of corrosion experiments run in 7 percent aqueous sodium chloride solution plus 3 percent hydrogen peroxide indicate that porosity and its location have considerable effect on resistance to corrosion. Inert-gas welded 5052-0 aluminum alloy specimens were most severely attacked, followed in severity of attack by oxyhydrogen and oxyacetylene welded specimens. Corrosion attack of oxyhydrogen weld is of concentration cell type. Intergranular corrosion occurred in heat affected zone of 2024-T3 alloy; oxyhydrogen welded specimens were most affected while inert-gas ones showed least intergranular attack.—INCO. 13813

### 3.7.3, 2.3.7, 3.5.8

**Evaluation of Weld-Joint Flaws as Reinitiating Points of Brittle Fracture.** D. C. MARTIN, R. S. RYAN AND P. J. RIEPEL. *Battelle Memorial Institute. Welding J.*, 36, No. 5, 244s-251s (1957) May.

Influence of various types and sizes of flaws in welded butt joints on initiation of brittle fractures studied under conditions simulating service conditions. Resume is made of literature survey on factors and circumstances that are known about brittle fractures in ship steels and similar materials. Development of test specimen and apparatus to evaluate weld-joint flaws is considered. Apparatus used is unique in that sphere becomes part of test specimen after disk is welded in. Sphere is sufficiently strong and notch tough at test temperatures to running-in fracture, and diameter is large enough to provide elastic energy to propagate fractures across test panel at velocities of 1000-5000 fps. Sphere and disks were of standard ship quality steel (0.10-0.15 nickel). Cracks were made by placing cast iron in weld joint when making weld in test specimen, and lack-of-fusion flaws were made by laying 3/8-in. thick plate along one groove surface. In investigating influence of cracks in welds, effects of test temperature, crack length, crack depth, cyclic loading and residual stresses were considered. Tables, graphs.—INCO. 14325

### 3.8 Miscellaneous Principles

#### 3.8.1, 3.4.3

**Rates of Corrosion Processes.** (In German.) W. KATZ. *Metalloberfläche*, 11, No. 5, 145-154 (1957) May.

Corrosion phenomena and corrosion reaction processes cannot be interpreted or predicted by thermodynamic data alone. The nature of the corrosion products formed and, consequently, their protective effect is another factor of importance which was thoroughly investigated by the author. The results of his research work plus the findings of other investigators may be summed up as follows: Corrosion processes which are not connected with the formation of a protective layer are linear functions of time and their rate is governed by the concentration and diffusion into the metal surface of the depolarizer in solution. In processes where a protective layer is formed the time dependence is governed by variations in the

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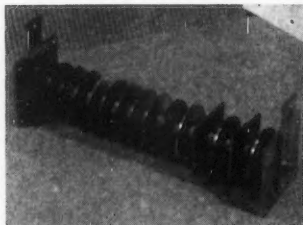
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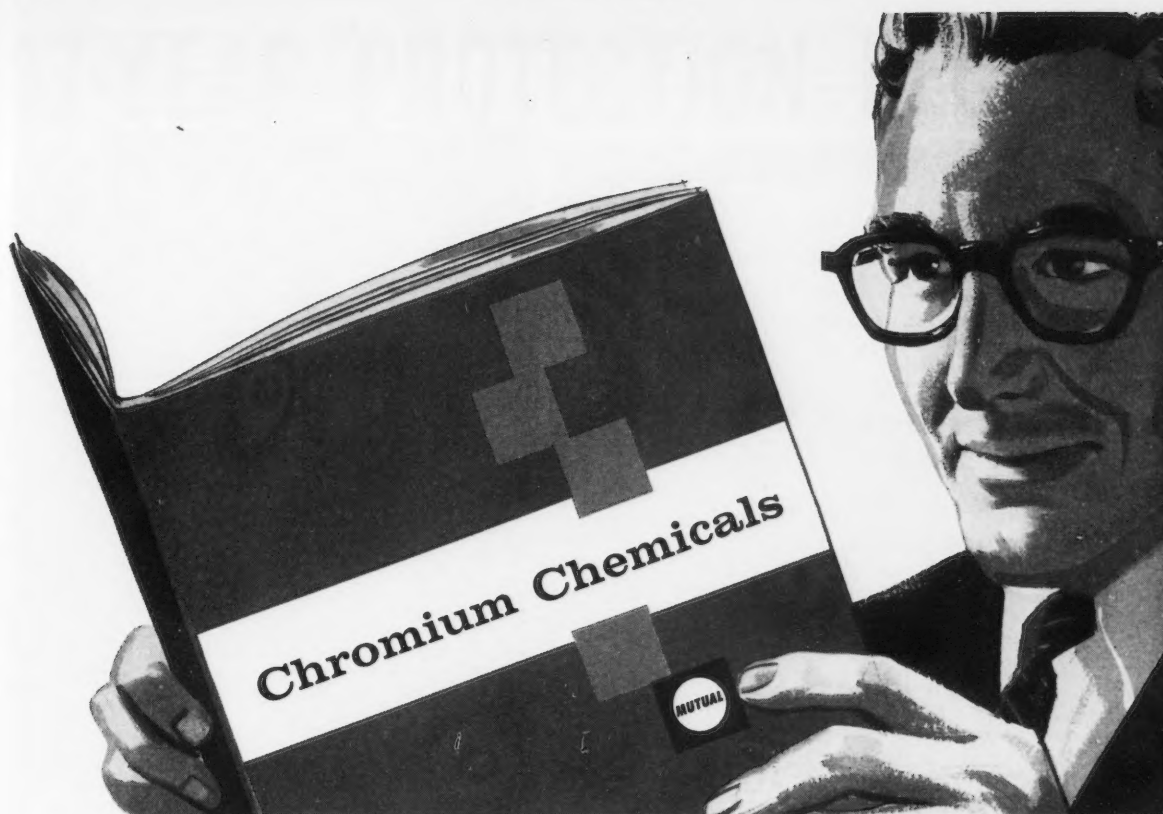
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surface area. This may be either a linear or a non-linear function. If the protective layer formed causes reduction in cathodic activity of the surface, the time dependence becomes a parabolic function, as it is observed in the MBV process of oxidizing aluminum. Corrosion with the formation of a boehmite film on smooth (as rolled) aluminum surfaces also follows the parabolic law, while rough surfaces show a logarithmic time dependence. The natural oxide formation of aluminum is also logarithmic.—ALL. 14085

## 3.8.2

**Application of Faraday's Law to the Anodic Dissolution of Metals.** (In

French.) I. EPELBOIN AND M. FROMENT. *Metaux: Corrosion-Industries*, 32, No. 378, 55-72 (1957) February.

The object of the article is to demonstrate that the application of Faraday's Law to the electrolyte dissolution of metals, such as aluminum, in particular, permits the discussion of the existence of ions having instable valencies. The anomalous dissolution of aluminum in perchloric acid is examined and, hence, conclusions are drawn as to the structure of the double electrochemical layer.—ALL. 14156

## 3.8.2, 5.8.3, 3.4.7

**Current Density, Potentials and Loss of Metal in Galvanic Cells with the e-Acceptors  $H_2O^+$  and Oxygen.** K. WICKERT, H. WIEHR AND E. JAPP. *Werkstoffe u. Korrosion*, 8, No. 1, 6-17 (1957) Jan.

Current densities, potentials and corrosion of galvanic cells were measured as functions of pH values for platinum, copper, brass, V2A stainless steel, iron, nickel, aluminum and zinc. Influence of e-acceptors  $H^+$  and oxygen in anode and cathode electrolytes upon the above mentioned electrochemical data was determined. It was concluded that values for activity of local elements, current density and potential must be determined in order to predict corrosion of metals. In some cases it is sufficient to know current density or potential. Influence of inhibitors upon electron transitions to e-acceptors was investigated; potassium chromate and sodium nitrite were studied. Graphs.—INCO. 13914

## 3.8.2, 6.2.5, 4.3.2

**The Electrochemical Behavior of Stainless Steel in a Sulfuric Acid Solution.** (In Russian.) N. IA. BUNE AND IA. M. KOLOTYRKIN. *Doklady Akad. Nauk SSSR*, 111, 1050-1053 (1956) Dec. 11.

Results of tests using a potentiostatic method for studying electrochemical and corrosion behavior of stainless steel (Type 1Kh 18N12T) in a solution of 1.0 N sulfuric acid.—BTR. 13978

## 4. CORROSIVE ENVIRONMENTS

## 4.2 Atmospheric

## 4.2.1

**Atmospheric Pollution.** A. C. MONKHOUSE. *Science Progress*, 45, No. 179, 418-428 (1957) July.

Reviews history of air pollution resulting in passage by Parliament of Clean Air Act of 1956, pollutants due to burning of coal and fuel oils, methods for preventing contamination of atmosphere by grit, fly-ash, and sulfur dioxide fumes, contribution of motor traffic to atmospheric pollution, and influence of meteorological conditions on air pollution. Reduction of sulfur dioxide remains an unsolved problem as long as coal and oil are used directly as fuels, except in very large fuel-burning installations. Systems involve costly apparatus, high running charges, and emission of cool, moisture-laden gases. Tables list composition of exhaust gases for petroleum and diesel engines under idling, accelerating, cruising and decelerating conditions.—INCO. 14737

## 4.2.3, 7.6.4, 6.3.6

**Fire-Face Corrosion of Domestic Copper Boilers.** C. C. HANSON. *Corrosion Technology*, 4, No. 7, 235-238 (1957) July.

Discusses corrosion of copper boilers

which occurs in domestic closed stove and advances theory explaining the phenomenon. While many authorities have attributed this type of failure to attack by sulfur trioxide or sulfuric acid, author contends that it is the stabilized compound of sulfur trioxide with ammonia, namely ammonium acid sulfate, which is the actual corroding medium. Ammonia may be from domestic waste burnt on fire or from residual nitrogen in fuel. Presence of ammonium acid sulfate was established by dry distillation and X-ray crystallographic examination of deposits from copper boilers. Suitability of other materials to replace copper was discussed. Graph showing corrosion rates in molten ammonium acid sulfate rates following in order of increasing attack: chromium-cast steel, aluminum-bronze, 18-8 stabilized, another aluminum bronze, and mild steel. Use of copper-clad steel and 18-8-clad steel is also considered. Graphs.—INCO. 14635

## 4.2.3, 7.6.4, 2.2.3

**High Temperature Corrosion of Alloys Exposed in the Superheater of an Oil Fired Boiler.** D. W. McDOWELL, JR., R. J. RAUDEBAUGH AND W. E. SOMERS. Paper before Am. Soc. Mech. Engrs., Ann. Mtg. Research Committee on High Temperature Steam Generation and Power Div., Chicago, November 13-18, 1955, 8+ pp. *Combustion*, 27, No. 7, 41-42 (1956) Jan.; *Trans. A.S.M.E.*, 79, 319-328 (1957) Feb.

To assist in determination of which heat-resistant alloys perform most satisfactorily in various high temperature corrosive environments, a series of test racks was installed in the gas inlet of second bank of superheater of boiler burning Bunker "C" fuel oil. Gas temperatures varied from 1560 F at full load to 1100 F at maximum load. Scale taken from buildup on test specimens analyzed as high as 36 vanadium pentoxide and 32 sulfuric anhydride. High vanadium, sulfur, sodium and calcium contents were present in ash. Corrosion rates are expressed as inches penetration during test and are extrapolated to IPY. Extensive metallographic examination was made of all specimens. Rack material was Type 330 and rods were Type 310. Test specimens were Types 406, 446, 302, 410, 321 and 431, Inconel, Incoloy and Types 309 and 430, 5 chromium and 5 chromium modified specimens, carbon steel, cast alloys HK, HE, HT, HF, and HW, and 2¼ chromium-1 molybdenum steel. Tables, photomicrographs.—INCO. 13821

## 4.3 Chemicals, Inorganic

## 4.3.3, 3.4.8

**Corrosion of High-Temperature Alloys in Sulfur-Bearing Cracked-Ammonia Atmospheres.** G. LEE ERICSON, WALTER J. BRAUN, FREDERICK W. FINK AND ROBERT S. PEOPLES. Battelle Memorial Institute. U. S. Atomic Energy Commission Pubn., BMI-1179, April, 1957, 32 pp.

The presence of sulfur in quantities up to 350 grains per 100 ft.<sup>3</sup> or cracked ammonia containing 43 volume percent of water vapor does not increase the corrosion of any of the stainless alloys subjected to tests at temperatures from 1200 to 1800 F. Any property changes are a function of temperature.—BTR. 14658



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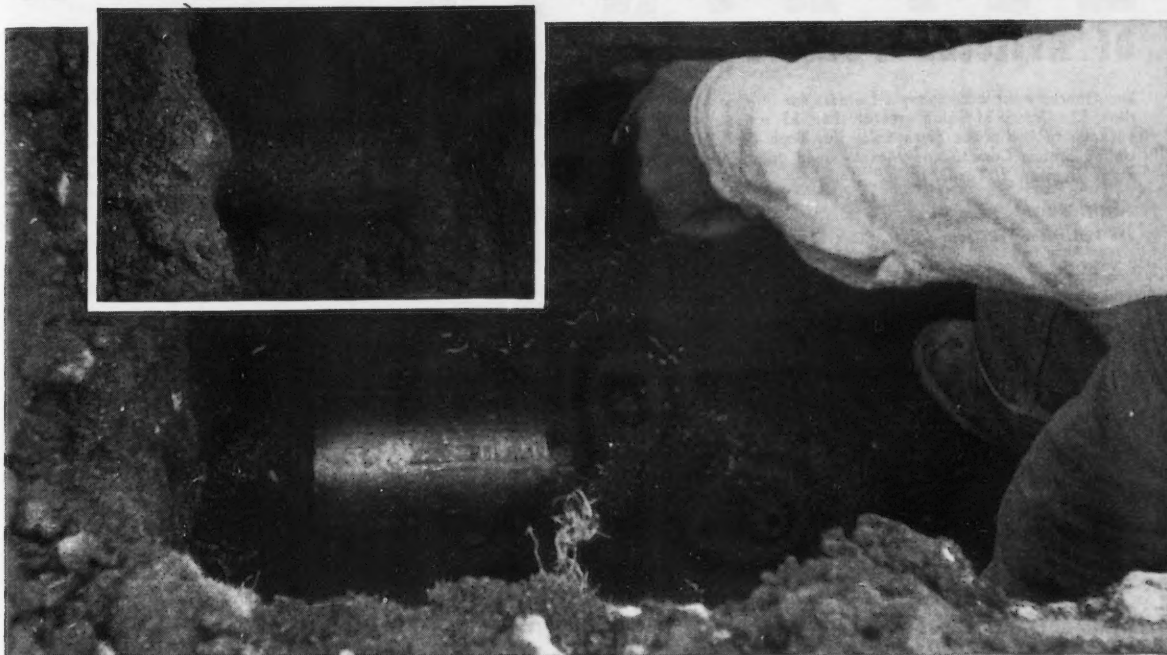
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(Continued on Opposite Page)



## 4.3.5

**Corrosion of Materials in the Presence of Fluorine at Elevated Temperatures.** MARTIN J. STEINDLER AND RICHARD C. VOGEL. Argonne National Laboratory, U. S. Atomic Energy Commission Pubn., ANL-5662, Jan., 1957, 22 pp. Available from Office of Technical Services, Washington, D. C.

Nickel and Monel are suitable materials for use in fluorine atmosphere at temperatures up to 550 C. At higher temperatures nickel and copper exhibited the lowest corrosion rates. Ceramic materials such as calcium fluoride and alumina resist attack by fluorine even at the highest temperatures, but lack mechanical strength.—BTR.

## 4.3.6, 6.3.6, 3.6.5

**Electrode Potentials and Rate of Copper Oxidation in Aqueous Solutions of Chlorides of Alkali Metals and Alkaline Earth Metals.** (In Russian.) V. M. KADEK AND L. K. LEPIN. *Latvijas PSR Zinatnu Akademijas Vestis*, No. 5, 107-117 (1957).

Solutions of potassium, sodium, lithium, magnesium and calcium in concentrations from 0.001 N to saturation were used. Initial rate of corrosion on copper is a maximum 2.6 mg per sq dm in saturated potassium chloride solution, and a minimum 0.30 mg per sq dm in saturated calcium chloride solution. Rate decreases with time and depends upon the oxidation product.—BTR. 14710

## 4.3.6, 4.3.2, 3.4.4

**Corrosion of Soft Steel in Alkali Mono and Alkali Hydrogen Fluorides. 1. Influence of the Concentration of the Solution Upon the Corrosion of Soft Steel.** (In German.) W. KOHLER. *Werkstoffe und Korrosion*, 8, 133-138 (1957) March.

Corrosion depends on concentration of the solution. In potassium fluoride and potassium fluoride-hydrogen fluoride solutions corrosion resistant coatings are formed, while in ammonium

fluoride-hydrogen fluoride solutions corrosion appears even at relatively high concentrations. 16 references.—MR. 13826

## 4.4 Chemicals, Organic

## 4.4.2

**Corrosion by Acetic Acid.** A Report of Task Group T-5A-3 on Corrosion by Acetic Acid (H. O. Teeple, Chairman), prepared by John A. Manning. *Corrosion*, 13, No. 11, 757t-766t (1957) Nov.

A summary of data and experience on the use of various materials of construction for the storage and handling of refined glacial acetic acid and dilute acetic acid, submitted to NACE Technical Practices Committee 5A-3 is presented. Discussion of common corrosion problems, laboratory and field corrosion test results and photographs of common types of failure are included.

Aluminum alloy or austenitic stainless steel tankage is recommended for the storage of refined glacial acetic acid. Austenitic stainless steel heating coils, pumps, valves and piping are recommended for both glacial and dilute acetic acid storage systems. The corrosion risk involved in the use of aluminum for dilute acetic acid storage is emphasized and the limitations on the use of copper and copper alloys for acetic acid storage are discussed.

The importance of minor contaminants and of the oxidizing or reducing nature of the environment is discussed in relation to choosing the proper materials for construction of acetic acid processing equipment. It is pointed out that the austenitic stainless steels and copper and copper alloys satisfactorily meet most of the acetic acid processing conditions though higher alloys or non-metallic materials may be required occasionally. Common corrosion problems encountered in acetic acid processing and control measures for such problems are discussed. 14399

## 4.6 Water and Steam

## 4.6.1, 5.8.2

**Role of Corrosion Inhibitors in Water Treatment.** E. L. STREATFIELD. Paper before Anglo-Belgian Corrosion Conf., CEBELCOR, Brussels, April 1-2, 1957. *Corrosion Technology*, 4, No. 7, 239-244 (1957) July.

Water softening processes, use of corrosion inhibitors to supplement conventional water softening or deionization, basic corrosion mechanism, and distribution of corrosion are briefly reviewed. Detailed evaluation is given of various anodic and cathodic inhibitors; organic inhibitors such as tannins; sodium benzoate, triethanolamine phosphate and sodium mercaptobenzthiazole in treating ethylene-glycol-water antifreeze solutions; and amines, particularly octadecylamine and quaternary ammonium salts of fatty amines. 12 references.—INCO. 14745

## 4.6.2, 7.4.1, 7.6.4

**Corrosion Protection for Industrial Steam Producing and Utilizing Installations. Pt. 2. How to Guarantee Protection of Equipment.** (In French.) R. MALICET. *Corrosion et Anti-corrosion*, 5, 216-220 (1957) July-Aug.

Types of corrosion encountered in different elements of steam installations; supply water and boiler water make-up, rate of vaporizing and generator design as

factors causing internal corrosion of piping; importance of correct operation of steam equipment by qualified personnel.—MR. 14738

## 4.6.2

**Iron Corrosion and Boiler Water Treatment.** (In Italian.) T. SONGA. *Metallurgia Italiana*, 49, 371-376 (1957) May.

Corrosion of iron in aqueous media; formation of a protective layer on iron by action of boiling water; influence of oxygen and alkalis; problem of copper in boiler water; caustic corrosion in boilers; corrosion preventives as established by experiments at Breda Institute, specialists in water treatment. 30 references.—MR. 14784

## 4.6.2, 5.7.6

**An Application of Hot Lime Zeolite to Moderate High Pressure Boiler Operations.** B. E. VARON AND S. B. APPLEBAUM. Paper before Am. Power Conf., Chicago, March 27, 1957. *National Engr.*, 61, No. 7, 24-29 (1957) July; *Blast Furnace Steel Plant*, 45, Nos. 7, 8, 758-760, 783, 785; 900-903 (1957) July, Aug.

Deals with experiences of Richfield Oil Corp.'s Watson Refinery with 2 hot process plants for their 600 and 700 psig boiler plants, the former a single-stage hot process without zeolite, and the latter a 2-stage hot lime zeolite process. Results are compared from both process plants operating at same time on same water for reducing hardness, alkalinity and silica to maintain boilers and turbines free from silica and other scale, carryover, and corrosion. Diagrams, tables.—INCO. 14807

## 4.6.2, 6.4.2, 5.8.2

**Corrosion Behavior of Aluminum Alloys in High Temperature, Pressurized Water.** ALAN B. RIEDINGER. Knolls Atomic Power Lab. U. S. Atomic Energy Comm. Pubn., KAPL-M-ABR-2, March 20, 1957, 31 pp. Available from Office of Technical Services, Washington, D. C.

Available data on the corrosion behavior of aluminum alloys in high temperature, pressurized water are summarized. The alloys most promising for use above 200 C are M 400, M 388, and X 2219. The corrosion rate of these alloys increases with increasing test temperature, increasing velocity, and increasing pH. Phosphoric acid and the polyhydroxyanthraquinone compounds act as inhibitors. (auth.)—NSA. 14826

## 4.6.2, 6.2.5, 3.5.8

**Stress Corrosion of Austenitic Stainless Steels in Steam and Hot-Water Systems.** C. EDELEANU AND P. P. SNOWDEN. *J. Iron and Steel Inst.*, 186, Pt. 4, 406-422 (1957) Aug.

Stress corrosion seems to occur only under pressure and temperature conditions which are consistent with the presence of a film of electrolyte on the steel surface, and only if certain impurities, such as chloride and caustic, are also present. In highly superheated steam, such as 600 C and 1500 lb/in<sup>2</sup>, no stress-corrosion cracking was found. Provided the steel surface is clean, ordinary creep data should be applicable in steam, but premature failures are likely with steel contaminated with chlorides, due to an oxidation effect. At lower temperatures, and particularly below 400 C, stress corrosion can occur with 1500 lb/in<sup>2</sup> steam, but probably only if the steel is contaminated. The cracking with chloride contamination is rapid only near the dewpoint and is slow at 20 C superheat.

## REPRINTS

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Corrosion of Austenitic Stainless Steels in Sulfuric Acid by E. H. Phelps and D. C. Vreeland .....	.50
Quantitative Comparison of Surface Finishes and Heat Treatment of Stainless Steel with Respect to Corrosion by Jet Fuels by R. G. Carlson .....	.50
Titanium, Zirconium and Tantalum for Control of Corrosion—A Review by William E. Lusby, Jr. ....	.50
Corrosion of Type 347 Stainless Steel and Aluminum in Strong Nitric and Mixed Nitric-Sulfuric Acids by C. P. Dillon .....	.50
Corrosion of Stainless Steels in Boiling? Acids and Its Suppression by Ferric Salts by Michael A. Streicher .....	.50

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An Electrical Resistance Method of Corrosion Monitoring in Refinery Equipment by A. J. Freedman, E. S. Trocinski and A. Dravnieks .....	.50

At much higher superheat values it may not occur. With caustic contamination there is cracking even at high superheat values. Oxygen seems to be necessary for chloride cracking, but not for caustic cracking. All the conventional austenitic steel compositions are considered susceptible to stress corrosion under really bad conditions.—BTR. 14643

#### 4.6.2, 3.2.2, 6.4.2

**Intergranular Corrosion of Aluminum in Superheated Steam.** CORNELIUS GROOT AND R. E. WILSON. *Ind. and Eng. Chem.*, 49, No. 8, 1251-1254 (1957) Aug.

To investigate temperature and pressure limitations for aluminum used in high temperature, water-cooled reactors, intergranular corrosion for aluminum alloys M-388 and 1100 in superheated steam was studied. The long induction period was a function of both temperature and pressure, but once intergranular corrosion occurred, it often destroyed a sample in a few hours. Alloy M-388 was more resistant than 1100, the reactivity of which varied with lots and was correlated with iron content. This type of corrosion for aluminum can be reduced by using M-388, or less effectively by increasing iron content of 1100.—BTR. 14640

#### 4.6.2, 6.4.2, 2.3.6

**Corrosion of Aluminum in High Temperature Water. Part II. Application of Infrared Spectra to Corrosion Studies.** R. M. HAAG. Knolls Atomic Power Lab. U. S. Atomic Energy Comm. Pubn., KAPL-1739, Feb. 28, 1957, 16 pp. Available from Office of Technical Services, Washington, D. C.

The application of infrared transmission measurements to corrosion studies has been investigated. Corrosion products may be identified in situ by reflectance measurements, or after removal from the base metal. Data are included from studies on aluminum alloys and hydrous aluminum oxides. (auth.)—NSA. 14638

#### 4.6.2

**Deposit Composition and Thickness.** R. T. HANLON. *Modern Power & Eng.*, 51, No. 1, 74-79 (1957) Jan.

Experimental boiler duplicated scale and sludge formation on internal boiler surfaces under conditions simulating boiler operation. Scales and sludges analyzed by chemical and physical methods provided better understanding of various mechanisms of formation and permitted visual examination of crystalline structures as they were deposited on boiler metal. Correlation was possible between deposit composition and apparent density of scales and sludges by microscope. Types of boiler scale and water treatment are discussed. Transfer effect, density of sludge, and sludge treatment are discussed. Photomicrographs, diagram, graph, 11 references.—INCO. 14420

## 5. PREVENTIVE MEASURES

### 5.3 Metallic Coatings

#### 5.3.2

**A Comparison of the Corrosion Behavior and Protective Value of Electrodeposited Zinc and Cadmium Coatings on Steel.** C. H. SAMPLE, A. MENDIZZA AND R. B. TEEL. Paper before Am. Soc. Testing Materials, Symp. on Properties, Tests, and Performance of Electrode-

posited Metallic Coatings, Spr. Mtg., Buffalo, Feb. 29, 1956, and 2nd Pacific Area Nat'l. Mtg., Los Angeles, Sept. 19, 1956. ASTM Special Technical Publication No. 197, 1957, 49-64; disc., 64-65.

Specimens of zinc and cadmium plate (0.00005-0.002 in. thick) on AISI 1010 cold-rolled steel were exposed to atmospheric testing at New York City, Kure Beach, N. C., Perrine, Fla., Point Reyes, Calif., and Steubenville, Ohio, as well as to accelerated 20 percent salt spray, 3 percent salt spray and fresh sea water spray (fog) tests. Data are summarized in tables, and graphs show % rust vs. time, and time to 50% rust vs. coating thickness. Results for an interrupted cyclic humidity test are presented for general information. Relative protective value of zinc vs. cadmium coatings varies with conditions of exposure and cannot be predicted by any single accelerated corrosion test. In some industrial atmospheres, zinc coatings last longer than cadmium of same thickness, while cadmium has longer protective life in marine and rural locations. Cadmium coatings have longer protective life in sodium chloride spray (fog) tests, while zinc coatings are superior if fresh sea water is used in test. Calcareous deposits formed on cadmium in sea water obscured fact that steel was corroding beneath it.—INCO. 14357

#### 5.3.2, 2.1.2

**The Corrosion Behavior and Protective Value of Copper-Nickel-Chromium and Nickel-Chromium Coatings on Steel.** C. H. SAMPLE. Paper before Am. Soc. Testing Materials, Symp. on Properties, Tests, and Performance of Electrodeposited Metallic Coatings, Spring Meeting, Buffalo, Feb. 29, 1956, and 2nd Pacific Area Nat'l. Mtg., Los Angeles, Sept. 19, 1956. ASTM Special Technical Publication No. 197, 1957, 7-21; disc., 21-24.

Summarizes objectives and conclusions of Programs 1, 2 and 3 of ASTM Committee B-8 Subcommittee II, dealing with relative durability of decorative copper-nickel-chromium vs. nickel-chromium coatings on bumper bar grade steel, and discusses importance of rating system employed in the tests. Various combinations of copper-nickel-chromium and nickel-chromium were exposed at New York, Kure Beach, Pittsburgh, State College, Pa., Coral Gables, Fla., and Detroit. In addition to the programs, panels of 0.01-mil chromium on buffed wrought "A" nickel, on buffed Watts nickel applied to wrought "A" nickel, and on bright nickel applied to wrought "A" nickel were exposed at New York and Kure Beach. Effects of thickness of cyanide copper under acid copper, salt spray (fog) test vs. atmospheric exposure, and effect of applying nickel coatings in two layers are discussed. On exposure in marine, rural and industrial locations, decorative chromium coatings, with underlayer of buffed Watts nickel applied directly to steel, maintain acceptable appearance longer than copper-nickel-chromium coatings of same total thickness. Decorative life of copper-nickel-chromium coatings exposed to weather decreases as ratio of thickness of copper to that of nickel increases. Nickel-chromium coatings with two-layer nickel (1st layer annealed and buffed or only buffed) are superior to 1-layer nickel coatings in marine, rural, and to lesser extent, industrial atmospheres. Tables, photomicrographs of specimens.—INCO. 14354

#### 5.3.2

**Structure of Chemically Deposited Nickel.** A. W. GOLDENSTEIN, W. ROSE, F. SCHOSSBERGER AND G. GUTZET. Paper before Electrochem. Soc., San Francisco, April 29-May 3, 1956. *J. Electrochem. Soc.*, 104, No. 2, 104-110 (1957) Feb.

Basic reactions of Kanigen nickel plating process are reviewed. X-ray and electron diffraction analysis of nickel deposit containing 7-10 w/o phosphorus revealed that the deposit has a dense amorphous structure. Structure is unrelated to nature of substrate, manner of preparation, and thickness. Deposit showed no porosity but in etched state revealed striations which were interpreted as banded variations in phosphorus content. Transformation characteristics of chemically deposited nickel are considered. As-deposited state is highly metastable and at 300 C or above reverts rapidly to equilibrium condition of phase mixture of crystalline nickel and crystalline Ni<sub>3</sub>P. Dispersion of Ni<sub>3</sub>P in nickel can be used as means to promote and control hardness of heat treated chemically reduced nickel. Photomicrographs, graphs.—INCO. 13823

#### 5.3.2

**Chromium Plating Over a Chromate Film.** J. E. HOOVER. *Globe Chem. Co., Inc. Products Finishing*, 21, No. 4, 46-49 (1957) Jan.

Study of chromium plating process showed that heat treatment of chromate films on electroplated zinc produces a surface which can be given a coating of chromium plate. Chromium plating obtained will give various degrees of protection in salt-laden atmospheres. Length of exposure before corrosion to base metal varied from 150-450 hours in a salt spray cabinet. Humidity tests were performed on chromium plated panels, and a maximum of 2,660 hours exposure was obtained during 1 experiment before small blisters were observed.—INCO. 13804

#### 5.3.4

**Application of Induction Heating to Metallic Diffusion.** N. A. LOCKINGTON. *Metal Treatment & Drop Forging*, 24, No. 136, 29-33 (1957) Jan.

Description of adaptation of induction heating methods to diffusion processes, whose mechanism of deposition is comparable to conventional "Chromicizing" methods. Mild steel, nickel, titanium and molybdenum were used as base metals for experimental diffusion treatments. Nickel does not respond so readily as mild steel to induction chromicizing, but diffusion can be effectively obtained. Advantages and limitations of process are discussed. Photomicrographs, tables, 11 references.—INCO. 13808

#### 5.3.4

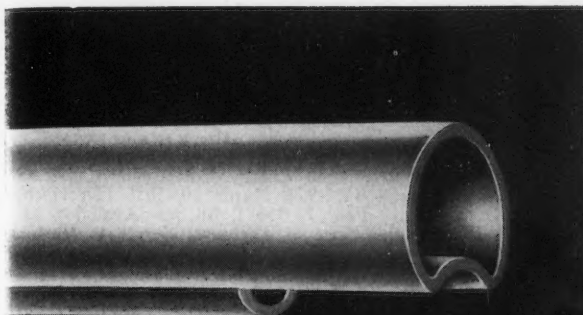
**The Significance of Surface Preparation Techniques in Production of Precious Metals Claddings.** H. SPENGLER. *Metall.*, 11, 500-506 (1957) June.

Survey of techniques for cladding steel, iron and non-ferrous metals with platinum metals. Classification of cladding methods and applications, discussion of cladding mechanism, and comparative descriptions of cladding procedures are included.—INCO. 14360

#### 5.3.4, 5.4.2, 6.6.4

**Preparation of Protective Coatings by Electrophoretic Methods.** A. C. WERNER



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and others. Vitro Corporation of America, U. S. Wright Air Development Center, April, 1957, 53 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C. (Order PB 131062).

Electrophoretic methods were tested

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for the preparation of protective coatings which would make molybdenum suitable for continuous, long-term operation in an oxidizing atmosphere at 1800 to 2000 F. Multilayer coatings of 80 percent nickel-20 percent chromium and nickel-bonded chromium carbide provided good static air-oxidation resistance. Inclusion of a 50 percent dense nickel-chromium layer brought satisfactory ballistic impact resistance. Erosion was fair. All panels, however, failed under severe thermal shock. Attempts at electrokinetic impregnation of graphite to produce oxidation-resistant coatings showed the process to offer no advantages for highly conductive materials. However, the build-up of surface

deposits indicated that electrophoresis would provide an excellent method of coating graphite.—OTS. 14381

### 5.3.4, 6.3.17

**Electrodeposition of Aluminum on Uranium.** J. G. BEACH, W. C. SCHICKNER, DELORES HOPKINSON AND C. L. FAUST. Battelle Memorial Institute, U. S. Atomic Energy Commission Publication, BMI-992, March 30, 1955 (Declassified Feb. 7, 1957), 18 pp. Available from Office of Technical Services, Washington, D. C.

Aluminum electroplating was studied in a search for new methods of cladding uranium fuel elements. Uranium electroclad with 12 mils of aluminum over a 0.5-mil nickel (or nickel plus copper) electroplate resisted corrosion for more than 100 hr. in boiling water. This quality of protection was effected by hot pressing the electroclad uranium with 5.1 tons/in<sup>2</sup> for 5 min at 950 F. The electroclad uranium without the hot pressing generally failed within 24 hr. The results with hot-pressed samples paralleled those of later experiments with hot-pressed wrought aluminum claddings on uranium. In both cases, the uranium was electroplated with thin (0.5 mil) layers of metals to prevent aluminum-uranium diffusion, to aid bonding, and to assist in corrosion protection. This aluminum electroplating study helped to define the importance of the intermediate coating between the aluminum and the uranium, the effect of good bonds between the various layers, and the effects of hot pressing in protecting uranium with an aluminum cladding. (auth.)—NSA. 14587

### 5.3.4, 3.2.2

**Galvanizing Embrittlement in Cold Bent Steel Pipes.** (In Japanese.) H. KIMIZUKA ET AL. *Sumitomo Metals* (Japan), 9, No. 1, 5-12 (1957) Jan.

Embrittlement occurred in low carbon rimmed steel pipes with very coarse ferrite grain size which had been subjected to severe cold bending and inadequate pickling. Strain ageing also affected embrittlement; the pipes were not brittle immediately after cold bending but became brittle on heating at a low temperature even if not galvanized. An effective remedy for pipes damaged by galvanizing embrittlement is said to be annealing after bending.—ZDA. 14679

### 5.3.4

**Corrosion Stability of Films Electrolytically Deposited on a Passivated Surface.** L. I. KADANER AND A. KH. MASIK. *J. Applied Chem., USSR (Zhur. Priklad. Khim.)*, 30, No. 7, 998-1006 (1957).

Preliminary passivation is found to increase corrosion resistance of both anodic and cathodic films and degree of uniformity of surface covered. 3 tables, 8 figures, 12 references.—ATS. (Available from Associated Technical Services, P. O. Box 271, East Orange, New Jersey.) 14660

### 5.9 Surface Treatment

#### 5.9.1, 6.2.5

**Corrosion Property of Stainless Steel Polished Chemically.** B. RO. J. *Chem. Soc. Japan*, Ind. Chem. Section, No. 6, 680-683 (1957) June.

Author tested the corrosion resistance of stainless steel previously finished by means of mechanical polishing, electropolishing and chemical polishing. The

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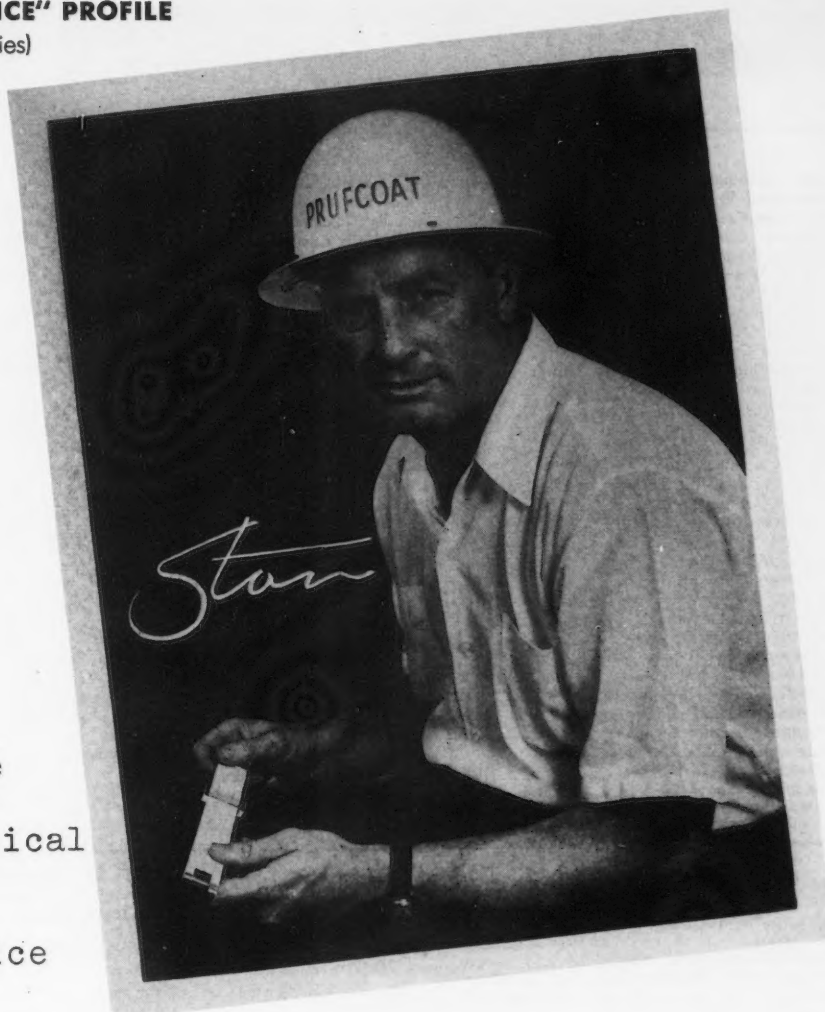
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corrosion of stainless steel decreased in the order sulfuric acid, hydrochloric acid, phosphoric acid and nitric acid. 25-chromium is more corrosion resistant than 13-chromium, while 18-8 is more resistant than 25-chromium. On the other hand, it was observed that surface finishing reduced the corrosion rate. Chemical polishing was superior than electropolishing, and further superior than mechanical polishing.—JSPS. 14345

## 5.9.1

**Chemical and Electrochemical Treatment of Corrosion Resistance Steels.** (In German.) O. P. KRAMER, *Metallwaren-Industrie und Galvanotechnik*, 48, 148-152 (1957) April.

Details of pickling, electrolytic pickling, protective coating, burnishing and coloring.—MR. 14330

## 5.9.1

**Treatments Prior to Painting or Oiling of Steel, Aluminum and Zinc Surfaces.** (In French.) C. HESS, *Corrosion et Anticorrosion*, 5, No. 1, 19-24 (1957) Jan.

The general principles of pre-treatment are described, emphasis being given to degreasing, passivation and the importance of the correct pH value to avoid electrolytic activity beneath the paint. Various industrial methods are described—crystalline and amorphous coatings, and oiled or waxed finishes for ferrous materials, light alloys and zinc. Phosphate and chromate treatments are briefly described.—ZDA. 14707

162a

## 5.9.2

**Chelating Agents in Metal Cleaning and De-Rusting.** J. K. AIKEN AND C. GARNETT, *Electroplating & Metal Finishing*, 10, No. 2, 31-35 (1957) Feb.

One of outstanding properties of EDTA (ethylene-diamine-tetra-acetic acid) group of chelating agents is their ability to dissolve water-insoluble metal oxides and hydroxides, carbonates, sulphates and phosphates which form as corrosion products. EDTA is valuable in special-purpose cleaning compositions and has advantages over both cyanides and polyphosphates sequestering agents. Although simple immersion in hot concentrated EDTA solution is often possible, cathodic treatment is preferred and under these conditions bond between basis metal and lowest layer of corrosion product is attacked. In immersion cleaning, EDTA is most effective as di-sodium salt but possibility of basis metal attack occurs; table gives weight losses for samples in 10 percent EDTA di-, tri- and tetra-sodium salt solutions, cold and boiling. An industrial derusting process is described.—INCO. 14871

## 5.9.2

**How to Clean and Etch Aluminum.** D. GARDNER FOULKE AND O. KENDLE IGENS, *Modern Metals*, 13, No. 4, 44, 46, 48 (1957) May.

This is a general review of cleaning and etching methods in use in aluminum fabrication. Each system is dealt with briefly; the following are included: solvent cleaning, emulsifiable solvents, emulsion cleaners, acid cleaners, alkaline cleaners, and acid and alkali etchants.

Additions of Sorbital, salts of hydroxy acids, or lignin sulphonate will prevent the formation of sodium aluminate refractory deposits in etching tanks. Typical pre-anodizing, pre-plating, pre-painting, pre-enameling (die castings) schedules are presented. A short reference to chemical conversion coatings concludes the article.—ALL. 1465

## 5.9.3

**Shotblasting Developments in Metal Surface Preparation.** J. CARLE, *Corrosion Prevention and Control*, 4, No. 5, 49-51 (1957). 14608

## 5.9.3, 8.4.5

**Applications of Ultrasonic Energy** (Progress Report No. 3 Covering Period from February 16, 1957 to April 15, 1957). Aeroprojects, Inc. U. S. Atomic Energy Commission Pubn., NYO-7917 May, 1957, 32 pp. Available from Office of Technical Services, Washington D. C.

Continued experimentation in the dissolution of stainless steel and Zircaloy-2, using close-proximity ultrasonic treatment, has resulted in the accumulation of substantial amounts of data on the effect of various reagent solutions. The use of fluoboric acid appears promising for the dissolution of Zircaloy-2; a solution of 5M nitric acid plus 1 M hydrochloric acid effects satisfactory dissolution of stainless steel with applied ultrasonics. Studies on the effect of pressure and applied r-f power on the rate of dissolution of Zircaloy-2 in an 80 percent sulfuric acid-20 percent nitric acid solution indicated retardation of the corrosion rate as the pressure was increased from atmospheric up to 270 psig. Increased power at atmospheric pressure produced significantly increased corrosion rates. Subatmospheric pressure showed a negligible effect on rate of corrosion. Exploratory work indicated promise for the technique involving direct coupling of ultrasonic energy to the material to be dissolved. Fabrication of the resistance-heated, controlled-atmosphere ultrasonic furnace for the treatment of thorium bismuthide melts has been completed. Ultrasonic transducer-coupling-punch systems for introducing both axial and shear-type vibration into powdered metals during compaction have been fabricated and assembled in a 100-ton hydraulic press. (auth.)—NSA. 14840

## 5.9.4

**Density and Porosity of Anodic Coatings on Aluminum.** RALPH B. MASON, *Metal Finishing*, 55, No. 8, 55-57, 67 (1957) Aug.

Toluene has been selected as the liquid to use in applying Archimedes' principle to the determination of the real density of unsealed and water sealed anodic coatings on aluminum. Density values were used to calculate the percent pore volume. Unsealed sulphuric acid anodic coating on 1100-H16 aluminum, prepared under standard conditions, had a density of 2.96 and a pore volume of 15.8 percent; the corresponding water sealed coatings had a density of 2.65. Similar coatings on 2024-T3 aluminum have lower densities but higher pore volumes, namely about 47 percent. Anodic coatings on 1100-H16 and 2024-T3 aluminum prepared in the more common electrolytes were investigated. There was little change in the density of coatings prepared in the oxalic acid electrolyte with rise in temperature, and the porosity increased only slightly. (auth.)—ALL. 14725



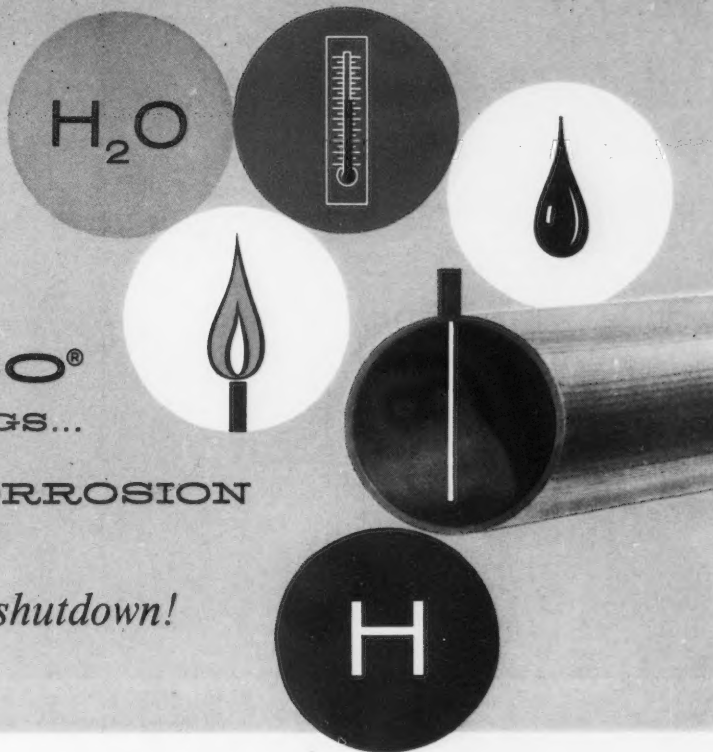
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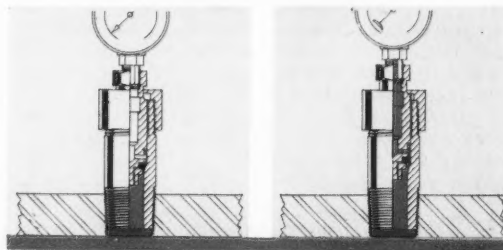
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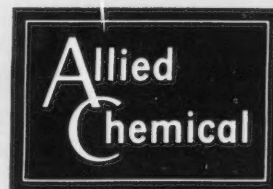
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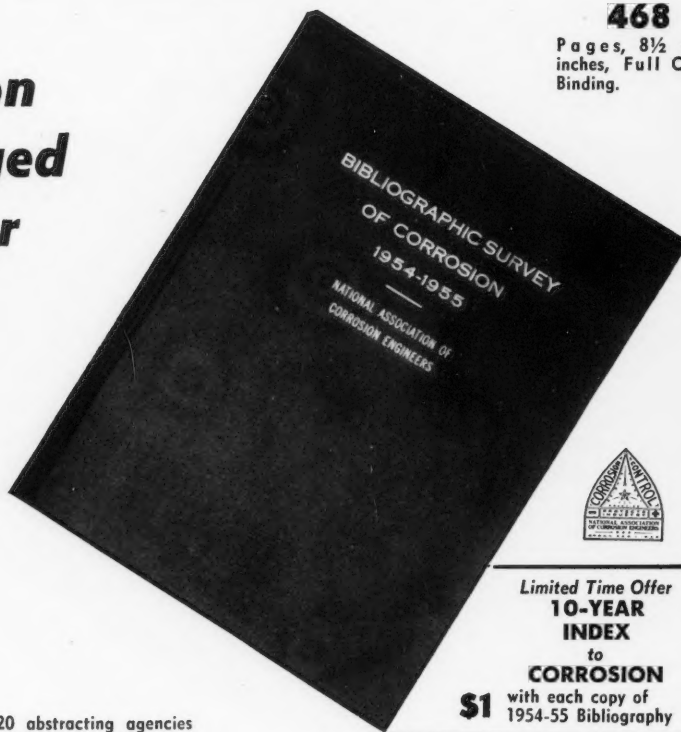
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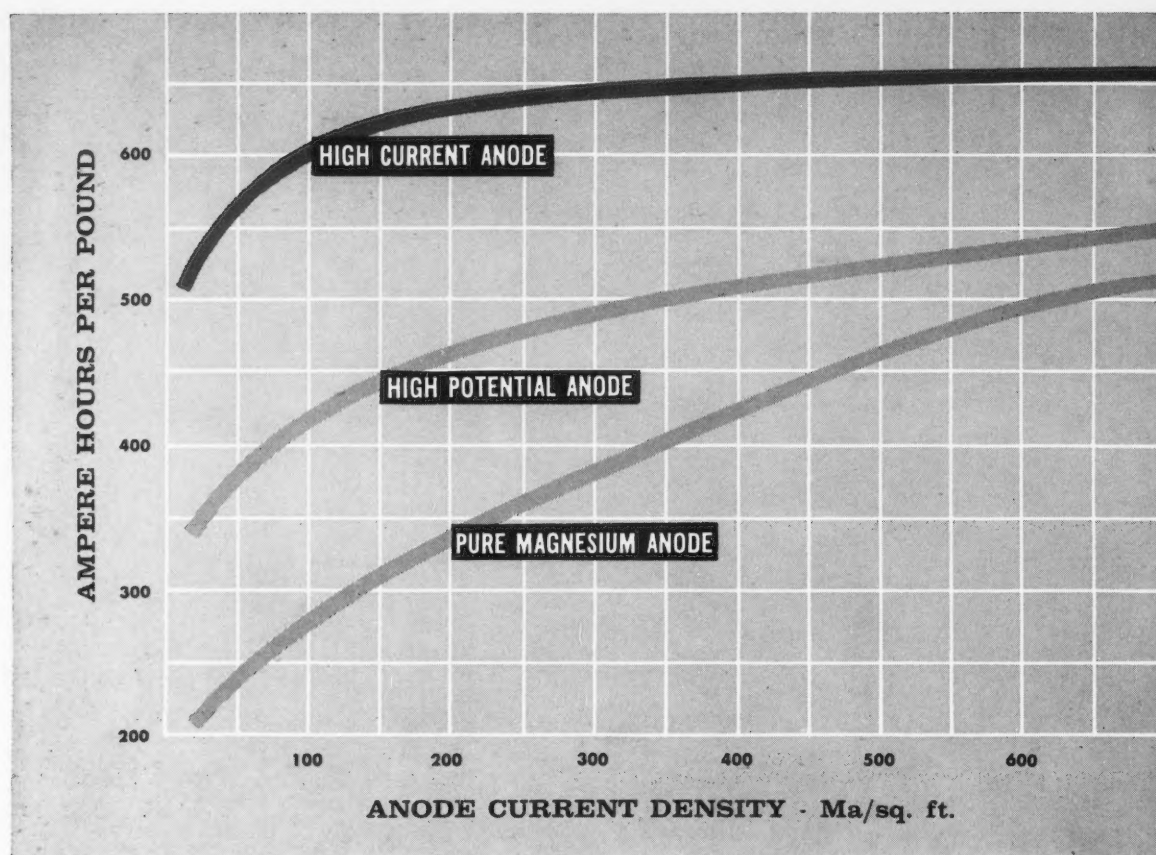


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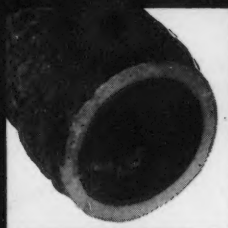


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Viscosity	2 maximum	1 maximum	1 maximum
Specific Gravity	1.183	1.180	
Acid Value	.14	.14	
Sulfur Content	<10	<10	

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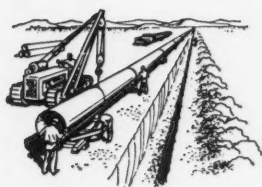
# DURIRON

ANODE  
DATA  
SHEET

Number  
**2**  
Ground Bed

Basic engineering information about DURIRON impressed current anodes for cathodic protection.

## Protection of a Pipe Line



**THE PROBLEM:** To protect a pipe line in a creek bed area where coke breeze could not be used due to sandy top soil and quicksand at a four foot depth. The very nature of sandy soil prevents adequate backfilling because it is very prone to caving. The original ground bed of bare scrap iron anodes had a high resistance and showed a tendency to dry out during the year. Adequate protection of the pipe line was not being achieved.

**THE INSTALLATION:** Twenty Duriron Type D Anodes (2" dia. x 60") were installed in two rows, 20 feet apart, with 20 foot spacing in each row as illustrated in Fig. 1. Soil resistivity averaged 2500 ohm-centimeters measured with the four pin method at 10 foot spacing. The anodes were jetted into place using a high velocity stream of water through a 10 foot piece of 1 inch pipe with the top of each anode eventually being approximately three feet below the surface (Fig. 2). Approximately 60 seconds were required to install each anode by this method. The anodes were connected to a 2/0 aluminum header, with the exception of numbers 4, 6, 16, and 17 which were connected to separate number 6 leads and were carried back to the rectifier and connected thereto with 0.01 ohm Holloway shunts. This made possible the reading of individual current values for these four anodes. The connection to the pipe line was by means of an overhead 4/0 copper cable, a distance of about 1000 feet.

**THE PERFORMANCE TO DATE:** This group of anodes produced 34 amperes (an average of 0.65 amp./sq. ft.) at 46 volts, and after approximately three year's time, these readings have not fluctuated appreciably. Based on initial readings, the resistance of single Type D anodes to ground is approximated by the expression  $R=0.005\rho$ . ( $R$  is the single anode resistance and  $\rho$  the soil resistivity in ohm-centimeters.) The loop resistance of sixteen anodes (all except the four with independent leads) was measured as 1.3 ohms; the four, together, read 3.9 ohms; and all twenty indicated 1.2 ohms. This indicates that Duriron anodes can be installed without backfill and operate at appreciable current densities with no noticeable tendency toward gas blocking. The jetting-in process used to install these Duriron anodes was reported to result in considerable savings. It would have been very difficult to install anodes in holes dug by the usual rotary drill method under the ground conditions described above, and it would also have been expensive to transport backfill to this relatively inaccessible locality.

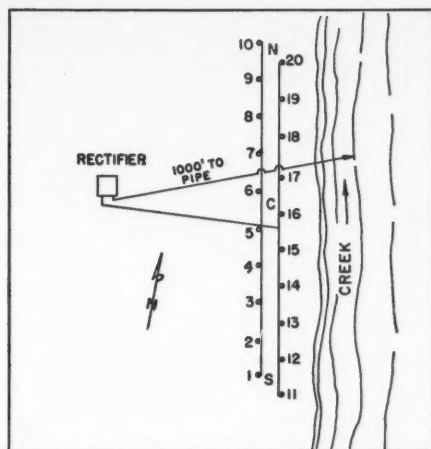


FIG. 1—Illustration of how Duriron Anodes were spaced.



FIG. 2—Illustration of jetting in process.

THE DURIRON COMPANY, INC./Dayton 1, Ohio



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